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Agricultural Research Service

METHODS FOR SEPARATING PITH-BEARING PLANTS INTO FIBER AND PITH

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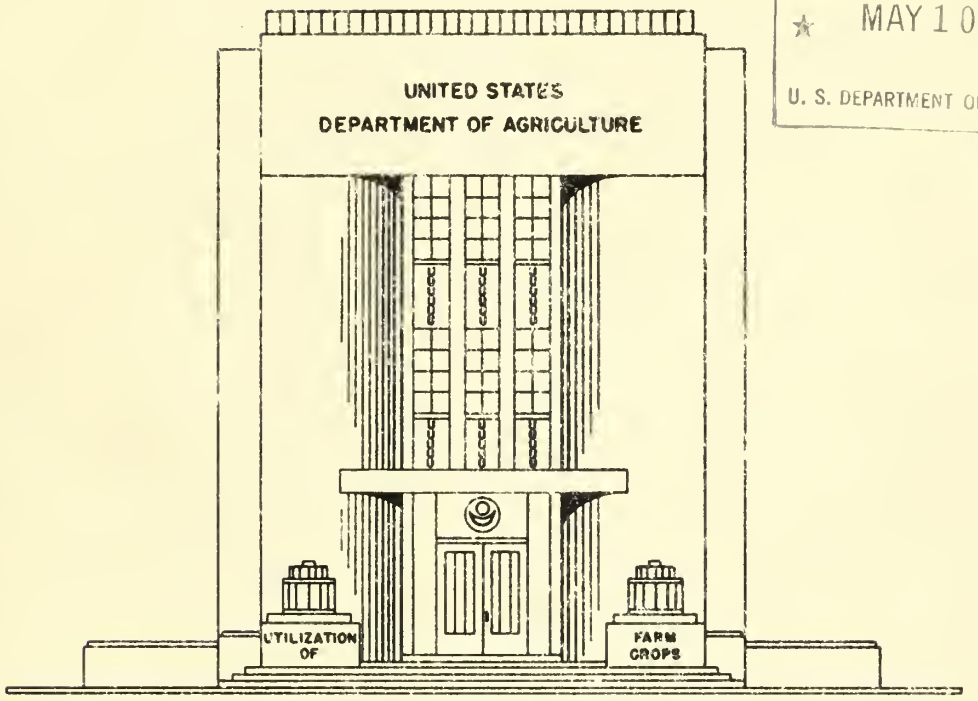

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MARCH 1955

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ARS-71-4

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METHODS FOR SEPARATING PITH-BEARING PLANTS INTO FIBER AND PITH

By

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INTRODUCTION

Many nonwoody plants that have been suggested for industrial utilization, particularly for papermaking, contain a much larger proportion of parenchymatous cells, or pith, than are found in most woods. Great dissimilarity in physical structures of pith and fibers rules out the possibility of easily obtaining homogenous end products from such plants.

For the purpose of this discussion, nonwoody, pith-containing plants may be divided into two groups. The first group comprises plants having outside rind fibers, more or less densely packed together, which enclose the major cross-sectional area of the plant, composed of pith cells, through which longitudinally run fibrovascular bundles and ducts. Sugarcane, corn, sorghum, papyrus, sunflower, hollyhock, noble canes, and reeds are examples of this class. Many of these plants contain from 25 to 50 percent pith by weight and a larger percentage by volume. To the second class belong plants having a woody-type stem, generally covered with bast fibers, which are associated sometimes with barklike material, the inside core of which is filled with pith. The percentage of pith varies with the size of this core. Plant stalks such as cotton, crotolaria, kenaf, soybean, and lespedeza are examples. Corncobs and certain varieties of wheat straw also contain considerable pith by volume.

With the increasing attention that is being given to the industrial utilization of nonwoody plants, particularly agricultural residues, it has become important to find practical methods for converting them into high-grade products. Of these plant materials, sugarcane bagasse has received the most consideration as a raw material for paper and board manufacture. It has long been recognized that to produce highest quality paper products from bagasse, pith should be eliminated. About three years ago the Northern Utilization Research Branch (NURB) undertook a sustained investigation to discover practical means for mechanically separating bagasse into substantially

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[1] Hawaiian Sugar Planters' Association, Honolulu, Hawaii. Collaborator with Northern Utilization Research Branch 1951-1952.

[2] One of the Branches of the Agricultural Research Service, U. S. Department of Agriculture.

pith-free fiber and fiber-free pith. The Hawaiian Sugar Planters' Association (HSPA) became interested in this problem at about the same time and through an agreement with the U. S. Department of Agriculture they placed three men as collaborators on the Northern laboratory staff. Studies to develop practical methods of separation were conducted in the laboratory and in the pilot plant at the Northern Branch and in several industrial pilot plants. This bulletin not only reports successful results of these studies but also describes methods now industrially in use which make less complete mechanical separations of pith and fiber.

BACKGROUND

Most previous efforts to separate pith from fiber have been directed to methods of purifying bagasse to suit it better for papermaking. The ultimate fibers of bagasse are of fine diameter, flexible, and have a ratio of fiber length to diameter that suits them for the manufacture of some of the finest papers. However, pith cells of bagasse are short, nonfibrous, and possess practically no felting power. If left in paper pulp, they decrease the drainage rate on the paper machine, make pulp difficult to bleach, decrease strength properties, and make the product more unsuitable for conversion into high-grade paper, particularly on fast-running, modern paper machines. During digestion to make pulp, pith consumes more chemical than fiber and yields but little pulp.

Failure of many previous attempts to use bagasse for papermaking may be attributed largely to the fact that little or no attempt was made to separate pith from fiber. Technical investigators in the field have recognized this fact for 50 years and many of them have advocated separation of fiber from pith. As a result, considerable effort has been made to find methods for doing this.

There have been two general approaches to the solution of the problem, methods depending on dry separation and methods depending on wet separation.

Dry Methods of Separation

The dry method would be simplest if it could be carried out effectively and sharply without a damaging effect on either component. Sherwood's patent No. 680,079 in 1901 deals with the mechanical removal of pith from plants and stalks, including bagasse, preparatory to making pulp. Wrede in 1911 claimed the use of rotary knives, followed by separation of fibers with rotary screens. The patent of Lee, No. 1,155,741 of 1915, directed claims to drying bagasse to a low moisture content in a current of gases of combustion, followed by breaking pith loose by the impact of a shredding or pulverizing device, then separating pith by using a series of screens or by air flotation. It will be noted that

all of these early processes consisted of a further disintegration of the bagasse and then separating the loosened pith by screening or the like. Arthur D. Little, Inc., who later turned to wet-screening methods, first used a dry-screening method in the Simmon process developed in Cuba for the United Fruit Company. According to this method, the bagasse was completely shredded before or just after leaving the sugar mill. It was difficult to shred the bagasse fine enough, but once this was accomplished the pith could be removed along with fine fiber. This was said to produce a clean fiber for pulping but an impure pith fraction.

A few years later, working with HSPA, Arthur D. Little, Inc. attempted use of the dry method but found that with Hawaiian bagasse the separation was incomplete. Other investigators have advocated similar methods of dry separation and have obtained results of the same general type. At the present time, several companies are using dry-screening methods commercially. None of these methods attempt a clean separation of bagasse into pith and fiber. In several cases the mixture of pith and fine fibers is used for fuel. In no case is pith-free fiber obtained for pulping.

If one examines pieces of bagasse carefully, it is easy to see why the dry method must prove unsatisfactory. Fibers of dry bagasse are harsh, stiff, and brittle. Pith cells are firmly embedded in bundles of rind fibers and cover the fibrovascular bundles. Material in stored bagasse is even more brittle and friable. When these dry materials are subjected to impact forces by shredders, hammer mills, disc mills, or the like, pith tends to be powdered rather than loosened and fibers are cut and fractured, producing many short, chunky fibers to which pith often is still attached. It is possible by screening to separate the mass into long and short fibers, but the long fibers still carry pith and in the short-fiber fraction pith and fibers are present in about the same ratio to each other as in the original bagasse.

Wet Methods of Separation

It is evident that if bagasse is wet, fibers will be more flexible and less friable so that mechanical treatment to loosen pith from fiber is not as likely to break long fibers into short pieces. Hammer mills have been used extensively in refining cooked bagasse for insulating board manufacture and their action in splitting and cutting fibers is well understood. When such fibers, free from pith, were obtained, many finer fibers were also produced which, during screening, were mixed with the pith.

One of the earliest wet methods is that of Manns, U. S. Patent No. 811,419 in 1906. He proposed removing pith by a digestion method strong enough to bring about its disintegration but not its destruction, after which the fiber is mechanically separated and

beaten. Viggo Drewson devoted much study to pulping annual plants and took out a series of patents on separating pith from bagasse, extending over a period from 1903 to 1917. An example was one involving cooking bagasse in caustic soda of sufficient strength to disintegrate pith only, then separating pith by screening, and cooking fiber to produce pulp. Scott of Arthur D. Little, Inc., as a result of his work with HSPA in 1917, obtained U. S. Patent No. 1,399,891 in 1921. The process consists of treating bagasse in a standard Hollander paper beater equipped with drum washers. By gradually lowering the beater roll, larger pieces of bagasse were broken up and pith loosened. At the same time, pith was removed from the beater through a coarse screen on the drum washer. It is reported that this produced an excellent separation. Fiber freed from pith and dirt remained in the beater and pith could be separated from wash water and be dewatered. It was felt, however, that the method would prove too costly to be practical largely on account of high power requirements of the beater. The large amount of water involved would increase pumping costs.

During the period 1925 to 1933, one of the authors[3] investigated without success a number of procedures, both wet and dry, for making a clean-cut fractionation of bagasse that might be practical from a cost standpoint. Pulping experiments at that time using Florida bagasse clearly indicated the advantages to be gained in preparing paper pulps from pith-free fiber. During this period, laboratory methods for fractionating insulating board pulps also were developed. This study led to a better understanding of the behavior of pith and fiber in water suspension, as related to screening, and of the conditions that would have to be met in a commercial separation process.

Whittemore and coworkers in 1935 studied methods for separating cornstalks into long fibers, pith, and fines (1).[4] The method developed consisted of a preliminary coarse shredding, preferably in wet condition, to minimize the production of fine material, washing the shredded material with water, breaking the pith loose from the fiber by passage through a single-disc mill at about 5-percent consistency, separating the long fibers by screening wet, and separating pith from fines and dirt by water flotation. This method did not prove to be practical.

Wells (2) in U. S. Patent No. 2,029,973, issued in 1936, proposed a method having some merit, consisting of fractional digestion to prepare fine pulp from pith-free fibers. The black liquor from the final pulping stage, still containing some caustic, was used for the first-stage digestion, which was carried out in a continuous fashion

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[3] E. C. Lathrop.

[4] Number in parenthesis refers to Literature Cited, page 48.

in a rod mill into which raw bagasse and hot black liquor were fed. Under the conditions in the rod mill bagasse was quickly wetted, pith cells were swollen and softened, and fibers were made flexible enough so that the rubbing which loosened the pith did not materially cut the fiber. Loosened pith and fiber were separated by use of a paper-mill screen, fiber was cooked in the final digestion stage, and pith was collected in a settling tank. It was stated that pith when blended with pulped waste paper supplied the necessary crush resistance to board made from the blend, to suit it for good corrugating medium. It is probable that this method or one similar might be practical if production of two mills, one for fine paper and one for corrugating board, could be properly balanced and if a market existed to absorb the production from both mills.

Most recent methods are those of Litkenhous (3), Horton and Keller (4), and the Northern Branch (5). In discussing problems involved in the utilization of bagasse for fine papers, one of the authors[3] pointed out to Litkenhous, when he was collecting the information for his report on bagasse for the War Production Board (6), that the problem of pith removal remained to be solved. As NURB was not then in a position to undertake the project, it was suggested that the subject was suitable for a chemical engineering thesis. As noted by Litkenhous, two graduate students at Vanderbilt University presented theses on the subject (Pollet 1946 and Hecht 1949). Methods for loosening pith involved the use of both hammer mills and rod mills. A study was made of various factors influencing these operations. The screen used for making the fiber-pith separation in water suspension was essentially that developed at this laboratory (7). The work was carried out on very small equipment and no cost data are reported.

At about this same time, work was undertaken by Keller at the Audubon Sugar School to develop a process for treating bagasse so as to recover additional sugar and effectively separate pith and fiber. Dry methods were tried in an exploratory manner but it was concluded that a wet process would be required. For the purpose of making the separation, a series of three special type hammer mills was used. Bagasse from the cane mill, with as little water as possible, was passed into the first hammer mill. Pith and fine fibers with water passed through the screen of this mill. Coarse fiber was carried to a second mill, and finally to a third in like manner. Material passing each of the three screens, which represented the pith fraction, then was passed over a drainer and the drained water, containing most of the sugar and water solubles left in the bagasse by the cane mill, was recirculated through the cane mill as maceration water. The fiber obtained was very clean and free from pith but represented less than half the weight of the bagasse. The pith fraction containing many short broken bagasse fibers was a mixture of about 40 percent pith and 60 percent short fibers. Work on this process is still under way (4).

In the development at the Northern laboratory of the mechano-chemical method for pulping agricultural residues such as bagasse and straw, the 3' Hydrapulper[5] shown in Figure 1 has been used. This type of machine is widely used in the paper industry to pulp waste paper and dry sheets of virgin pulp. The machine is an open tub, in the bottom of which is a rotor driven from below. This rotor is a flat plate having vanes attached to its upper surface which, depending on size of the machine, vary in height from an inch to several inches. The peripheral speed of the rotor is high and its action is to cause a violent circulation of contents of the tub, producing a very pronounced vortex. The Hydrapulper when used for pulping waste papers is supplied with a set of extraction plates placed in the bottom of the tub surrounding the rotor. These plates are perforated with various sized holes through which a suspension of pulped material is continually drawn off from the pulper, while water and waste paper or pulp is continually added. In using the Hydrapulper for cooking by the mechano-chemical process, the extraction plates are replaced by solid plates and the cooking is carried out batchwise. During the cooking process, particularly at high consistencies, a considerable amount of friction is developed in the circulating mass which results in a defibering action.

Since the action in the Hydrapulper is one of rubbing with a minimum of cutting, the first trials using it to loosen pith from fiber proved successful. It was found that the highest consistency at which a good vortex was maintained gave the best results. The pulper also proved to be a good machine for wetting the bagasse, an action requiring a few minutes. Pith was uniformly loosened from fibers in a period of about 15-to 20-min. circulation. The findings of this preliminary work were reported in 1951, together with estimates of tentative costs for pith separation (5). Extension of this work is now reported.

EXPERIMENTAL

The objective of the work was the development of the most efficient and economical method for separating pith from fiber so that each component could be recovered as a quality product practically free from each other.

Process development logically divides itself into two steps, the first of which deals with mechanisms for loosening the pith, followed by the development of means for separating the loosened pith and fiber. It was recognized that the quality of bagasse varied with the local conditions of variety, climate, harvesting, and

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[5] Mention of products or companies is not to be construed as an endorsement of these products or firms by the U. S. Department of Agriculture.

milling so that arrangements were made to secure bagasse from a number of regions and, if possible, several varieties within a region. Samples were obtained, generally in lots of a ton or more, from Louisiana, Florida, Hawaii, Mexico, Puerto Rico, Formosa, and the Philippine Islands.

The proximate chemical analyses of samples as determined by NURB are given in Table 1. Technical Association of the Pulp and Paper Industry (TAPPI) methods of analysis were used for all determinations, excepting for lignin which was determined by a method previously reported by this laboratory (8). It will be noted that differences exist between the amount of extractives in samples of whole bagasse, particularly hot water and alcohol-benzene extractives. Most samples were obtained directly from the cane press and were either air-dried or artificially dried. These samples contained slight amounts of sugar and other solubles. Samples of fiber and pith from each were obtained by a wet-separation process and most of the solubles were extracted in the processing. Since the alcohol-benzene soluble material consists in part of waxes, the rubbing action during separation process removed some of the wax which was dispersed in the process water. It will be noted that amounts of extractives are lower in stored bagasse, in which sugars have been destroyed by fermentation processes which have taken place.

Percentage of fiber, pith, solubles, and dirt found in representative samples of bagasse is given in Table 2. It is difficult to obtain an accurate estimate of these constituents although a number of methods have been studied for making the determinations. The analyses reported were made as follows: A bale of bagasse was broken up, the material thoroughly blended, and divided into 4 samples of about 15 to 20 lb. A moisture determination was made on a subsample and the remainder, after weighing, was steamed in an autoclave in the presence of about 3 times its weight of water for about 20 to 30 min. at 5 lb. pressure using live steam, relieving the pressure in the autoclave several times to remove air. The purpose of this steaming was to soften pith and fiber and to remove air from pith cells so that they would be completely saturated with water. The entire mass was removed from the autoclave, together with any free water and passed through a 24" double-disc refiner fitted with waveline plates, the setting between the plates being 0.3". This treatment effectively loosened pith from fiber bundles. All liquid draining from fiber was collected and mixed. Aliquot samples were dried and ashed to determine total and volatile solids. Treated fiber was dried to constant weight at 105° C. A subsample of this was extracted with cold water to dissolve remaining solubles and wash off dirt. This extract was analyzed for total and volatile solids and results obtained were added to those from the earlier determination. Any lumps in dried material were carefully broken up by hand and material was

successfully screened over 3 reciprocating screens dressed with perforated sheet metal plates having 0.436"-, 0.156"-, and 0.095"-diameter holes, respectively. Material remaining on screens was collected as fiber. Material passing all screens consisted of pith and fine fibers. In order to determine the proportion of each in the latter fraction, 3-gram samples were treated for 3 min. in a Waring Blendor in the presence of 500 ml. water containing a trace of detergent. This treatment broke up large pith cells but produced very little cutting of fine fibers. Materials in suspension were then classified by means of the Bauer-McNett fiber classifier. Material retained by the 14-mesh screen was classified as fiber. The remainder, containing only a small number of fine fibers, was considered to be pith. By careful inspection of fiber fraction it was estimated that it contained less than 5 percent pith. Data presented in the table were obtained from these procedures.

The samples differ considerably in their contents of pith, fiber, and dirt. These differences are inherent in the varietal characteristics of cane. For example, Table 3 shows how three varieties of cane grown in Florida differ in pith and fiber content.[6]

The length of the pieces of bagasse in the samples listed in Table 2 showed that their milling was probably different. As will be noted later, these and other physical properties not easily measurable resulted in notable differences in the behavior of bagasse samples while they were being processed in the Hydrapulper.

Methods for Loosening Pith from Fiber

If moist bagasse is rubbed vigorously between the hands, the pith will be loosened from the fiber without any damage to pith or fiber. Two types of machines have been found that simulate this action--machines of the Hydrapulper type and disc refiners.

A device for testing the completeness of pith loosening consists of a cone 10" in diameter at the top and closed at the bottom, formed at a 50-degree angle of 28-gauge metal perforated with 1/16" holes on 1/8" centers. The sample to be tested is placed in the cone which is dipped up and down in water several times. When the water draining from the cone runs clear, the sample is removed from the cone and examined visually for amount of pith still clinging to the fiber. This test which may be made very rapidly was found most useful.

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6 Private communication, B. A. Bourne, United States Sugar Corporation, Clewiston, Florida.

Hydrapulpers

The first test made to loosen pith from bagasse fiber, using the 3' laboratory Hydrapulper fitted with a solid rather than an extraction plate, was successful. The consistency of treatment was as high as possible--about 7 percent--cold water was used, and time of treatment was 30 min. After a few further tests it was apparent that a number of variables in the operation required study.

The Hydrapulper has an 18" rotor and is powered with a 25-hp. motor. The rotor has a peripheral speed of 3,780'/min. A recording wattmeter was provided to obtain data on power usage. The pulper could be heated with live steam. The following variables of operation were studied: Temperature of water, consistency, time of treatment, character of bagasse, method of adding bagasse to pulper, and effect of arrangement and number of vanes on rotor.

Effects of Temperature. Most of the bagasse available for use was dry and difficult to wet. Warm or hot water readily wets the bagasse, with the further advantage that both pith and fiber will be softened. Trials with water of different temperatures showed that hot water was more effective than cold water. However, water at 150° F. or over softened the pith so that the separated particles on drying were in the form of a fine flour and hence lost a good deal of their adsorptive capacity. On the other hand, when treatment was made in cold water, pith particles were so granular that many of them would not pass a 1/16" screen. A temperature of 100° to 120° F. was chosen for the test work since this would be practical in the Tropics. Also at this temperature, size of pith particles seemed to be about optimum. In studying the effect of temperature it was noted that friction produced in the mass during treatment also raised the temperature in the pulper by about 15° F.

Consistency. Two tests were made on samples of the same bagasse to determine effect of consistency. The first test was made at a consistency of 6.7 percent and the second at 4.9 percent. Treating time for both tests was 30 min. and all other variables were the same. It was evident on screening a water suspension of the fibers from the two tests that loosening of pith in the 4.9-percent test was not as extensive as in the other test. At the lower consistency internal friction and rubbing action developed in the mass of fiber were less than at high consistencies.

Effect of Vanes on Rotor. It was discovered very early in the work that bagasse composed of coarse, long fibers was more difficult to treat than finer bagasse. In an effort to treat a sample of coarse unshredded Hawaiian bagasse (NRRL No. 9573) from the Ewa Mill, two different rotors were tried. In the first trial, a rotor having 3 outside vanes 2 3/8" high and 3 inside vanes 1 1/2" high was used.

With this rotor, at a consistency of 6.7 percent, circulation in the Hydrapulper was not uniform and depithing was unsatisfactory. When a rotor having 18 outside vanes 7/8" high and 8 inside vanes 11/16" high was used, mixing at 6.7 percent consistency was very uniform as demonstrated by the power curve on the wattmeter which was steady and showed a power demand 1 to 2 hp. above that drawn in the first test. This latter type of rotor was standardized for the remainder of the study.

Charging of Bagasse to Pulper. If the bagasse is to be rapidly wetted when added to the pulper, it must be charged in such a way that a strong vortex is maintained. If most of the water was added to the pulper and then all of the bagasse at one time, it was often difficult to establish a good vortex in this small machine and maintain desired consistency. By trial and error it was found that in general the smoothest operation was obtained by adding two-thirds of the calculated amount of water, followed by half the bagasse, then by the remainder in portions, and adding more water when necessary to maintain the vortex. In this way, circulation at the highest consistency was obtained. In the early tests the charge of bagasse treated was 30 lb. Later tests showed that more uniform results were obtained when the charge was increased to 50 lb.

Two lots of bagasse taken from the same Hawaiian mill, one air-dried and the other kept in a moist condition, were tested in the pulper under identical conditions. As might be expected, the damp bagasse depithed more rapidly than the dried, since practically no time was required to wet the former.

Data in Table 4 are representative of carefully controlled runs using Hawaiian Laupahoehoe mill and Oahu mill bagasse. The conditions used were: Initial pulping temperature 100° F., consistency 7.1 percent, pulps screened in rotary screen at slow rate to obtain maximum separation, drain water from the dewatering screen filtered to remove solids, and filtrate collected and analyzed for total solids.

Time of Treatment. Some data on this variable are given in Table 4 and further data in Table 5. By using the cone test it is possible to estimate very closely when the treatment in the pulper has produced a maximum loosening of pith. Data in these tables show that the time of treatment depends on the particular bagasse used. In general, coarse bagasse is more difficult to treat and requires longer treatment. With some samples of bagasse it is difficult in the small machine to obtain circulation at high consistency. This appears to be related to pith content and gross physical quality of the material.

It was possible to determine from the wattmeter power curve the point at which maximum loosening of pith was reached. When bagasse is first added to the pulper, only a portion becomes wet immediately,

but as wetting increases, power usage reaches a maximum. At this point fiber seems to have comparatively little water-holding capacity and water itself circulates more rapidly than fiber. As pith becomes loosened, surface area of the mass of bagasse increases very rapidly until the mass of bagasse and water circulates as a unit. During this period power usage drops from a maximum to a minimum when depithing action is complete.

Experiments Using Extraction Plates. Some preliminary experiments were made using the pulper equipped with an extraction plate having 3/8"-diameter holes. With the draw-off valve closed, required amounts of water and bagasse were added to produce a high consistency in the pulper and the mass circulated for 15 min. At that time the draw-off valve was opened for 1 min. while water was added at about the same rate that it was being drawn off. A large amount of pith and dirt with some short fiber was removed. The valve was closed and water was added to the Hydrapulper to obtain a vortex. Stirring was continued for 5 min. The valve was opened again for 1 min. while water was being added, then closed and the cycle repeated. Each time the valve was opened less pith and more fiber drained off. After the third cycle, most of the material passing through the extraction plate was short fiber. Evidently, as the pith was removed, cutting of fiber took place due to the increased freeness of the material which caused the vanes of the rotor to produce a cutting rather than a circulating action. Further experiments using an extraction plate to screen out pith were held in abeyance because it was necessary to study methods of separating pith from fiber by various screening methods, in which work the pulper had to be used to loosen the pith in a standard manner.

Later, studies of this method showed that after the pith had been loosened by the batchwise pulper treatment it could be washed from the machine without much loss of fine fiber. For this purpose an extraction plate perforated with 1/8"-diameter holes proved best. Pith could be washed from the Hydrapulper through the extraction plate with about 2 changes of water in about 2 min. By passing the pith and fine fiber over a Jonsson screen plate perforated with 0.076" holes, the longer fiber could be recovered. The method has the advantage of providing a rapid and practical way to wet-up dry bagasse and loosen pith in the same operation. The method was used at the Northern Branch to treat 12,000 lb. of Florida bagasse. Results of this processing are given in Table 6.

Experience with 8' Hydrapulpers in Treating Bagasse. The HSPA purchased an 8' Hydrapulper and built a rotary screen based on the preliminary studies at NURB. Through an error the manufacturer supplied the pulper with an extraction plate having 1/2"-diameter holes instead of solid plates. The vanes on the rotor were designed for pulping waste paper. The peripheral speed of

the rotor was too low. Difficulty was experienced in operating at more than 4.5-to 5.0-percent consistency. HSPA discussed this matter with the supplier who recommended that holes 2" x 4" be cut in the extraction plate and stated that 6 percent was the highest consistency recommended. The Northern laboratory learned of this difficulty at the start of the collaborative work and joint steps were taken to remedy the situation. Solid plates replaced the extraction plates and the speed of the rotor was increased. It was found that it was possible to operate for a cycle of about 30 min., depending on the character of bagasse, at 7.5-to 8.0-percent consistency. When operating at lower consistency, HSPA had used a temperature of about 200° F. and cycles of up to 3 hr. It had naturally been concluded, previous to taking the corrective steps, that the method was impractical for use in the larger 8' Hydrapulper.

Under a Research and Marketing Act contract with USDA, The College of Forestry of the State University of New York made an extended study of the manufacture of shipping containers from Florida and Hawaiian bagasse. During the course of this work, 6 tons of Florida bagasse, variety F. 31-436 (1951-52), were depithed by treatment in an 8' Hydrapulper to loosen the pith, after which the material in the pulper was diluted and pumped to a Jonsson screen for separation into fiber and pith fractions. A description of this operation follows: The Hydrapulper located at Syracuse has a tub diameter of 8' and a rotor diameter of 4'. The rotor operates at approximately 4,000 f.p.m. peripheral speed and has 1 1/2"-high outside vanes and 2"-high inside vanes. Power for the unit is supplied by a 75-hp. motor. Vertical baffles made from 6" x 6" wooden beams were installed on the sides of the pulper to improve circulation.

The first depithing run was made on June 25, 1952. The bagasse bales were thoroughly broken up before being fed to the machine. It was found that the pulper did not have sufficient power to maintain circulation at the desired consistency, 7 to 8 percent. For this reason it was not possible to thoroughly wet the bagasse by feeding it into only enough water to give 7-percent consistency. The following modified process was worked out whereby the bagasse was first thoroughly wetted, then the consistency raised for depithing:

1. An excess of water (approximately 600 gal.) was drawn into the Hydrapulper and heated to 80° C. by direct injection of steam. Condensation of steam added another estimated 100 gal. of water. The object of heating the water was to to reduce the time required to wet the bagasse although this practice was contrary to the general NURB process since it was known to cause a size reduction in pith. In this instance, however, pith was run to the sewer, hence its quality was not important.

2. Bagasse (approximately 440 lb., air-dried) was added rapidly and circulated for 15 min. with steam injection continued to maintain temperature at 80° C. At end of the 15-min. period all bagasse appeared to be thoroughly wetted.

3. Excess water was then drawn off slowly within a period of 5 to 10 min. through a plate in the bottom of the Hydrapulper, which was perforated with 3/32" holes, until bagasse began to hold up along the sides of the pulper and block circulation. As the water was removed, current used by the motor rose to an overload of a maximum of 95 to 100 amp. Although it was impossible to accurately determine the consistency at this stage, it appeared to be about 6 percent.

4. The machine was operated for 40 min. after the maximum consistency had been attained, samples being taken from time to time to follow the depithing action. In several of the runs additional water was drawn off after 20 or 30 min. to compensate for water entering through the packing gland.

5. The Hydrapulper charge was diluted to approximately 2 1/2-percent consistency and pumped to a storage chest with a 4" trash pump fitted with a screw feeder.

The depithed bagasse was screened wet on a Jonsson screen having 0.25" perforations--the same size as that used at NURB. The consistency of screening was about 0.4 percent. Fiber discharged from the Jonsson screen was collected in a pile for cooking. Quality of this fiber in terms of amount of pith retained was slightly below that produced at NURB with the same Florida bagasse.

Disc Refiners

All earlier tests with disc refiners to loosen pith had been at low consistencies, 5 to 8 percent, and had resulted in considerable defibering and cutting of the fiber. When the necessity of using the principle of internal friction to loosen pith was recognized, trials were made with the 24" double-disc refiner working at higher consistencies.

Small-Scale Tests. In the first series of exploratory tests, the refiner was fitted with waveline plates (Bauer), Nos. B-1677 and B-1678. These plates have a wave pattern when viewed in radial cross section. The crest of the wave on one plate meshes with the valley on the opposing plate. Both plates have radial ribs on contact surfaces.

Bagasse used was from Oahu, Hawaii (NRRL No. 9903) and was selected because it had been shipped damp and, therefore, could be wetted more easily. To insure thorough wetting, the bagasse

which was very finely shredded was soaked in hot water in a small rotary digester for approximately 2 hr. It was then drained to approximately 85 percent moisture and fed to the refiner.

Seven short runs were made at clearance settings varying from 0.100" to 0.250" and the products were examined visually. It was the consensus of opinion that the 0.225" setting resulted in the best compromise of loosening pith on one hand and cutting fiber on the other. In other words, at settings of greater clearance, the loosening did not appear adequate and at less clearance a large percentage of fibers were cut. Remainder of the bagasse was then processed at the 0.225" setting.

The bagasse from the disc mill was fed over the Jonsson screen fitted with a 0.117" screen, then the separated pith was re-screened through the Jonsson with a 0.076" screen.

Following the refiner runs, bagasse from the same lot, No. 9903, was treated in the Hydrapulper for 12 min. and screened in a manner identical to that used for the disc-refiner material. Fiber and pith fractions from these runs were examined visually and both fiber fractions appeared to contain fiber of approximately equal length and equal pith content, and the pith fractions seemed to be of equal quality.

It was suggested that the capacity of the refiner could be increased by running at still wider plate settings and feeding bagasse at still higher consistencies.

Two types of plates were used in this series of tests, the waveline plates described and devil-tooth plates Nos. 1424-1425. Using waveline plates, settings were varied between 0.500" and 0.225" and consistencies of feed were varied between 18 and 38 percent. It was difficult to feed at consistencies much above 25 percent due to the small opening for feeding into the disc-mill plates. The devil-tooth plates were tried because it was thought that their construction would tend to produce more internal friction in the mass of fiber being treated at even wider plate settings. With these plates, settings up to 0.600" were used and consistences were varied as with the waveline plates. It was found that when higher consistencies of bagasse were fed, satisfactory pith loosening was obtained with wider plate settings, while power requirements were reduced and mill capacity increased. At any particular consistency, closing the gap between plates produced more defibering and cutting, consumed more power, and reduced capacity. A visual comparison of all of the results indicated a preference for the devil-tooth plates at a plate setting of 0.500". Fiber and pith so produced could be screened easily and both were of acceptable quality. Figure 2 shows the double-disc refiner provided with a conveyor for controlled feed and with drain box for collecting treated bagasse used for these studies. Figure 3 shows patterns of waveline and devil-tooth plates used.

These results were most promising. They indicated that loosening of pith might be carried out continuously rather than batchwise and that power requirement and capital investment in machines would be less than when the Hydrapulper method was used.

Trials with Commercial Refiners. Accordingly, a cooperative arrangement was made between Bauer Brothers Company's Fiber Products Laboratory, Springfield, Ohio, and NURB to carry out a testing program using commercial disc mills. Fiber Products Laboratory had available a 6' rotary digester, 36" commercial single- and double-disc mills, conveyors for controlling feed to mills, recording instruments for collecting operating data, and laboratory facilities for making analyses.

For the purpose of these tests and other work, about 2,000 lb. of bagasse were shipped to Springfield. This shipment consisted of bales of Florida variety Nos. CL. 41-223 (NRRL No. 9940) and F. 31-436 (NRRL No. 9941) and Hawaiian variety No. 1933, Oahu Sugar Company (NRRL No. 9851). In order to thoroughly wet the bagasse and expel air from pith cells, it was steamed in 200-lb. lots in the 6' rotary for about an hour at 5 lb. steam pressure with a solids to liquids ratio of 1:3. No water drained from fiber when the digester was dumped. Material was allowed to cool and was stored in galvanized cans.

First tests were made using a Model No. 400 36" double-disc mill, driven by two 150-hp. motors and dressed with devil-tooth plates set at openings of 0.600" and of 0.500". The two plates were rotated in opposite directions at 1,200 r.p.m. The disc mill was fed by a controlled calibrated conveyor. Data were obtained on rate of feed, consistency of feed, power consumption, and quality of product.

Operating characteristics and quality of product duplicated Peoria results. Capacity of this disc mill was disappointing. Many changes were made in manner of feeding but bulky character of the moist (25-percent consistency) bagasse and the fact that this material had to pass between the narrow spokes of a rotating disc made it impossible to feed at high capacity unless large amounts of water were used to force the feed. This, in turn, decreased consistency of treatment and greatly increased power consumption. Best results were obtained using devil-tooth plates with a setting of 0.5". Under these conditions indicated capacity of mill was 65 o.d. tons/day, with a power requirement of 2 hp./daily ton.

Tests were made with the 36" single-disc mill, Model No. 245, driven with one 150-hp. motor (Figure 4). This mill has a forced screw feed, the feed entrance being through the stationary plate in the mill. No difficulty whatsoever was experienced with the feed to this mill. First plates tested with this refiner were the devil-tooth pattern. Contrary to the experience with the

double-disc unit, these plates at wide-open settings were not effective in stripping pith from fiber. As the plates were brought nearer to contact, effectiveness of pith removal was increased, but fibers were cut. A set of plates having radial bars with rounded corners was tested with similar results.

Plates of waveline pattern were then tested with entirely satisfactory results. This design had been tried in the Peoria double-disc refiner and judged unsatisfactory. These contrasting results illustrate the difference in characteristics of single- and double-disc refiners. Bauer engineers said these differences were encountered in much refining work.

After numerous variations in setting of waveline plates and rate of feed, optimum conditions were arrived at as follows: Plate setting 0.050", rate of feed 110 o.d. tons/day, and power 1.0 hp./daily ton. Results of these tests are presented in Table 7.

For purposes of design, a rate of 100 o.d. tons bagasse/day at 25-percent consistency and a connected load of 150 hp./refiner to provide a power reserve for changes in variety of feed and desired quality of product were adopted. These tests provided data directly translatable to factory design.

The hp./ton required for loosening pith is established at 1 hp./daily ton as against about 2.7 hp./daily ton for the Hydrapulper method. The disc mill required is of a less expensive type than that used for refining paper pulps since tolerance between plates does not need to be exact. It is probable that other specially designed plates might prove to be better than any tried thus far. Any type of single-disc refiner which is capable of forced feeding when equipped with proper plates should be satisfactory for use.

In April 1954, a commercial trial of the single-disc mill at a sugar mill was carried out. The disc mill was provided with a 75-hp. motor and a forced feeding device, and was of the older type used for dry grinding. Bagasse, directly from the sugar mill of a moisture content of 49 to 50 percent, was fed at varying rates, using both waveline and devil-tooth plates. In this trial waveline plates proved better than devil-tooth which was the experience in the pilot-plant tests. The disc mill was operated at a capacity of about 100 tons bagasse (o.d.)/day, requiring only 0.5 hp./daily ton bagasse. It was found, however, that pith was not satisfactorily loosened from fiber under these conditions. An analysis of the processed, dried, and screened fiber showed that it still contained about 12 percent pith as contrasted with 5 percent when bagasse was processed in the pilot plant at moisture content of 75 percent. Visual inspection of screened fiber showed presence of large chunks of pith surrounding fibrovascular bundles. On the other hand, the rind fibers were found to be quite free from pith particles.

This trial showed that there must be sufficient water in bagasse to swell and soften pith around fibrovascular bundles, before passage through the disc mill, so that the pith can be rubbed from the fibers. Commercial-scale trials using bagasse of approximately 70 to 75 percent moisture content are planned. It may be expected that hp. requirements for processing in the disc mill will increase with increased moisture content of bagasse.

Separating Loosened Pith and Fiber in Water Suspensions

A variety of methods for making a sharp separation of pith and fiber were investigated. These included separation by wet screening and use of the Centri-Cleaner, a wet centrifugal method.

Wet-Screening Methods

The purpose of this investigation was to find the screen design combining in the most satisfactory way such features as efficient and complete separation of pith and fiber, high capacity, high-feed consistency to reduce pumping costs, and simplicity.

Data are presented for the three types of screens which were tested--a rotary screen, a Jonsson or submerged vibrating screen, and a flat-diaphragm submerged screen. Although other commercial screen designs were reviewed, the screens were not tested because the design did not seem suitable or a small-scale unit was not available.

Separation of bagasse pith and fiber by wet screening differs from most screening operations in the pulp and paper industries. In the first place, it is not simply a size separation since the fiber bundles are as small in diameter as the pith. Furthermore, the coarse product which is retained on the screen constitutes 60 to 70 percent of the amount fed the screen, whereas in normal pulp-mill screening only a very small percentage of this material, classified, as rejects, is obtained.

Several different lots of Florida and Hawaiian bagasse used for the wet-screening tests were all treated by a standard Hydrapulper method to loosen the pith.

As a result of an extensive testing program with various types of screens, the following principles of operation have been found necessary for a satisfactory separation of pith and fiber:

1. Screen design and operation must be such that fiber bundles will be carried parallel to screen surface. This condition is necessary to prevent fiber bundles nosediving through screen perforations.

2. Fiber bundles must be kept in constant motion, first, in order that loose pith may be washed through the fiber, and second, to convey clean fiber out of the separation zone.

3. Since movement of pith during screening is downward through the perforations, it is necessary that pith cells be thoroughly wetted so they will sink instead of float above the screen with the fiber.

The detailed description of the screening test work which follows is confined to three screen designs tested in the laboratory.

Rotary Screen. A small rotary screen was designed and built at the Northern laboratory. The screen consisted of a cylinder 14" in diameter by 90" in length, fabricated from perforated sheet metal with 0.117" holes on 5/32" centers. The screen rested at an angle of 9°, partially submerged in a tank of water. Treated bagasse at a drained consistency of 15 percent was fed to this screen by means of a slat conveyor. Since bagasse at 4-percent consistency can be pumped by a ball pump, water was mixed with fiber from the conveyor to furnish a feed of 4-percent consistency to the screen. Fiber was moved forward inside the screen by means of an internal helix 5" high of which there were 10 1/2 flights. Immersion of screen in a pond of water at feed end produces a consistency within the screen of about 0.5 percent. By trial it was found that 23 r.p.m. gave the best results with the screen described. More rapid revolution set up turbulence in the tank, thus retarding screening efficiency. A screen of a larger diameter would require a lower r.p.m. Pith which passed through the screen settled, for the most part, to the bottom of the tank and could be removed by mechanical means. Figure 5 shows screen in operation. The smaller screen to the right in photograph was used for dewatering pith.

The rotary screen met the necessary screening conditions referred to above as follows:

1. Fiber bundles were kept parallel to screening surface by a circumferential wave created by rotation.

2. The internal helix kept fiber bundles in motion and conveyed them to the discharge end.

3. It also had the advantage that fiber could be fed to it at about 4-percent consistency and discharged from it at about 10-percent consistency. This would be important from the standpoint of water requirements.

When handling small batches of depithed bagasse, the rotary screen performed a satisfactory separation. However, with larger batches (30 to 50 lb.), pith tended to accumulate in suspension around the

screen and to reenter the screen. As a result, screening efficiency was reduced at the end of the run and it was often necessary to rescreen in order to get a satisfactory separation. Several alterations were considered as means of overcoming this difficulty. They included use of a slat or screw conveyor in the bottom of the tank to continually remove pith at fairly high consistency or use of a greater volume of water at the feed end to keep flow of pith in one direction through the screen. The changes were not tried, however, when it was found that the Jonsson screen had greater capacity. In addition, it became evident that it would be difficult to scale up the rotary screen and maintain the required wave pattern.

Maximum capacity attained with the laboratory rotary screen was 5.2 sq. ft./lb./min. on the basis of dry bagasse. It is evident that the rotary screen is at a disadvantage in capacity when expressed in this way because less than one-half of screen surface is submerged at a given time. With the Jonsson or flat screen, nearly all of the screen surface is submerged at all times.

Jonsson Screen. The Jonsson is a commercial screen of submerged vibrating type which is fed on the upper screen surface. Pith passes through the screen and fiber is carried on top.

The experimental model[7] which was tested at the laboratory had a total screen surface of 6.78 sq. ft., approximately 80 percent of which is submerged. The screen assembly was mounted on four coil springs and was vibrated by an eccentrically loaded shaft which was driven at 1,400 r.p.m. by a 2-hp. motor. The vibrational pattern caused the fiber to move toward discharge end on the screen surface.

In the screening zone near the inlet end, submerged bagasse was in turbulent motion. As a result, some short fibers passed through the screen with pith. Toward the discharge end a loose fiber mat was formed which was carried forward on the screen.

The test screen was mounted in a rectangular tank with flat bottom and an opening on one side for pith discharge. During each run, material accumulated under the screen at both ends of the tank. This material was mostly the denser fraction--short fibers and dirt or sand. The tank in which the commercial-size screen rests has a sloping bottom giving a dished profile similar to the screen itself, and it is believed that there would be no accumulation of pith under the screen with this design.

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[7] Supplied under a loan agreement by Bird Machine Company, South Walpole, Massachusetts.

Variables considered in the test work on the Jonsson screen were size of screen perforation, consistency and rate of feed, and depth of water in screen. Procedure used in carrying out a test follows:

1. Bagasse with pith loosened from fiber in the Hydrapulper was charged into a 500-gal. mixing tank and diluted to desired consistency.

2. Dilute bagasse slurry was then pumped to headbox on the Jonsson screen located on the floor above. The feed box was fitted with a recycle connection to mixing tank in order that the feed rate to the screen could be varied by raising or lowering the sliding gate. Figure 6 shows tank and piping system used in connection with the Jonsson screen and Figure 7 shows the screen itself in simulated operation.

3. Each run was timed and drop in level in mixing tank was recorded. Dilute pith slurry which passed through the screen was collected in a second 500-gal. tank, measured for volume, and sampled for consistency.

4. Dilute pith slurry from most of the runs was rescreened through the Jonsson fitted with a screen having 0.076" perforations.

Numerous preliminary runs were made to determine operational procedure. Following these tests, 14 closely controlled runs were made with screens ranging in size from 0.08" to 0.44" perforations. A tabulation of test data for these runs appears in Table 8.

Screening consistency for each run was calculated by dividing weight of solids recovered by total weight of slurry fed as measured by drop in level of feed tank. The recovered-solids figure consisted of dry weight of fiber plus weight of pith obtained by multiplying the consistency times the volume of pith tank.

The apparent fiber content, percentage of total discharge, was calculated by dividing dry weight of fiber by total solids discharge. This value was used for comparison of fiber recovery from run to run. Actual fiber yield on basis of original bagasse would be less than this value because of loss of solubles and fines in pith slurry consistency determination.

Capacity of each screening test has been expressed as square feet of screening area/lb. of material discharged/min. This value was obtained by dividing 6.78 sq. ft., the total screen area, by total discharge rate.

The percentage of tailings removed by rescreening was calculated by dividing dry weight of tailings collected over the screen by total solids recovered. This value is indicative of amount of coarse material which passed through the screen with pith in the initial separation operation.

A Bauer-McNett classifier analysis is given for pith fraction of initial separation for each run. These pith samples were collected over the vibrating dewatering screen described on pages 25-28 and oven-dried.

Because of the turbulent motion in screening zone as described above, it was not possible to produce in a single-screening operation fiber free of loose pith and pith free of fiber. Under proper operating conditions, the fiber fraction was discharged relatively free of pith. However, these conditions required a low feed consistency and, as a result, short fibers passed through with the pith. With progressively larger perforation sizes, higher consistency of feeds could be used up to a maximum of 1.1 percent. Beyond that point the blanket of fiber on the screen was too thick to allow all pith to pass through.

The extent of the passage of short fibers through the screen is evidenced by amount of material retained by the 8-mesh screen in the Bauer-McNett analysis. Table 8 shows that this fraction ranged from 10.8 percent with the screen perforation of smallest diameter, 0.08", to 39.2 percent with the 0.44" screen. A further indication of short-fiber loss is the percentage of tailings removed in pith rescreening. This value increased from 15.2 percent with the 0.09" screen to 57.8 percent with the 0.44" screen. Only with the 0.08" screen did the first-pass pith appear to be of comparable quality to that separated in the rotary screen. Use of an 0.08" screen was impractical, however, because the capacity was low and a very low feed consistency was required to produce a clean fiber. Therefore, it was apparent that rescreening of pith fraction was required regardless of screen size selected.

The remaining features involved in determination of most satisfactory screen size were capacity, quality, and percentage of fiber. Capacity was found to increase directly with increasing screen-hole size. As mentioned above, fiber of good quality was produced from each screen depending upon consistency of feed, with increasing consistency permissible with larger screens. Upon these two considerations, it would appear that the largest screen size was the most satisfactory. However, in going from 0.25" to the 0.44" screen, the percentage of fiber recovered dropped and the percentage of tailings in pith increased sharply. Since it was very important to minimize the loss of fiber into the pith or tailings, the 0.44" perforation was

judged too large. Therefore, on the basis of this test work, it was concluded that the best conditions of operation for the Jonsson screen were a 0.25"-hole screen and a 0.9- to 1.0-percent feed consistency. The resulting capacity was 1.3 sq. ft./lb./min.

Pith fraction from the Jonsson screen under the above conditions was too coarse for direct use. It was found that pith could be readily rescreened using a Jonsson screen having smaller perforations so that a high-quality pith was obtained.

In the pith-rescreening operation, the only screen size tested was 0.08". This screen was very satisfactory for removing short fibers. Capacity for this operation was limited by the output of the 3" pump feeding the screen. Undoubtedly, rescreening capacity would be at least as high as for initial screening since there is substantially less of the reject or fiber fraction. If capacities are equal, the amount of screen surface required for secondary screening in terms of percentage of initial screening surface would equal the percentage of solids passed through the initial screen. In other words, if 40 percent of material fed to the Jonsson screen passed through, then 40 percent as much screening surface would be required for pith rescreening.

Flat Screen. A flat diaphragm screen was tested as a fiber-pith separator with flow of pith downward through the screen. The screen consisted of a box 90" long, 18" wide, by 15" deep, fitted with a rubber diaphragm across the bottom. A round-hole perforated screen extended the full length of the box approximately 4" above the diaphragm. The diaphragm was vibrated up and down 450 times per min. by a rotating shaft fitted with eccentric cams. A discharge port for pith was located in the side of the box between screen and diaphragm. An adjustable weir in the discharge port was used to control the level of water in the screen. Figure 8 is a photograph of the flat screen in operation.

The screen box was filled with water to a level approximately 3" above the screen surface at inlet end. At this depth a standing wave pattern was formed by vibration of the diaphragm. This wave pattern was necessary to orient the long fibers.

Hydrapulper-treated bagasse was fed into one end of the box at 0.7- to 1.0-percent consistency. Fibers aligned themselves parallel to the screen surface and were raised and lowered with the wave motion. Loose pith was drawn through the screen on downward surge of the diaphragm.

The screen was tested at angles varying from a slight upward to a slight downward slope. A hand rake was used to move fiber from feed end of the screen to other.

A total of 8 runs were made using the flat screen. Capacity data obtained in 4 runs are listed in Table 9.

In general, difficulty was experienced in finding a suitable method of conveying fiber along the screen. Raking had the disadvantage of compacting fiber bundles and thereby preventing discharge of loose pith. Water jets were tried but they diluted the pith slurry to an undesirable extent.

Fiber obtained from the flat screen contained a slightly greater amount of pith than was obtained from the Jonsson screen at comparable feed consistencies and screen sizes. The pith fraction contained slightly less fiber as shown by the Bauer-McNett analysis. This result was indicative of the fact that alignment of fibers parallel to screen surface was better with the flat screen.

Capacity of the flat screen using the screen plate having 0.19" holes was substantially less than the Jonsson screen. Maximum capacity was equivalent to 1.8 sq. ft./lb./min. compared to 1.3 sq. ft./lb./min. for the Jonsson screen.

Capacity of the test flat screen probably could have been increased had a more suitable means of conveying fiber been arranged. There are diaphragm screens available commercially which use an over-head rake-type conveyor in conjunction with water jets to move the product along the upper surface of the screen. Under these conditions, capacity of a diaphragm screen in separating bagasse would probably be equivalent to the Jonsson screen.

At completion of the test work it was concluded that the Jonsson screen gave the best results, particularly from the standpoint of capacity.

The Jonsson screen, as well as the diaphragm screen, had the added advantage over the rotary of being commercially available units.

It will be noted that screen capacities, as compared with paper-mill results, are very low. Consistency of the accepted pith fraction particularly is low (about 0.25 percent). This requires handling of very large volumes of water in recovering pith. For this reason other methods of separating pith and fiber were sought.

Using the Centri-Cleaner

The Centri-Cleaner is a new device being used in the pulp and paper industry to separate bark and other particles from pulp (9). Bauer Brothers Company called attention to the fact they had completed a pilot-plant installation of this machine and stated they believed the Centri-Cleaner would separate bagasse pith

from fiber. Accordingly, arrangements were made to test this device at the same time that the above-reported tests were made on the disc refiners. Bagasse treated in the single-disc refiner was the material used in the Centri-Cleaner tests.

The experimental Centri-Cleaner, shown in Figure 9, is conical in design. It differs from other centrifugal cleaners such as the Vortrap and Dirtec in that the conical section is longer for greater centrifugal force and the size is larger for greater capacity. A suspension in water of materials to be classified is pumped tangentially into the top of the cone of the cyclone. Cones are made with different thicknesses of vinyl plastic linings so that the entering orifices are 4", 3", or 2" wide. The suspension is pumped under pressure--40 to 60 p.s.i. The angle of slope of the cone is 10° so that as fluid travels to bottom of cone, velocity increases rapidly. The opening at bottom of cone is 2" in diameter. Bottom outlet may be reduced by fittings to 1/4" diameter. Change in size of this orifice causes changes in effective flow pattern within cone, particularly the vortex. With smaller orifices material coming from bottom orifice is of higher consistency. Centrifugal force throws heavier particles to sides of cone so that they are rejected at the bottom. Material having the greater specific surface is carried up in the vortex and emerges at atmospheric pressure at top of cone.

Since no trials with long fibers and pith such as constitute bagasse had been made with the Centri-Cleaner, it was decided to experiment first with a mixture of pith and short bagasse fiber produced as tailings by screening Hydrapulper-treated bagasse over the Jonsson screen.

After a number of tests with a suspension of 0.26-percent consistency, very high quality pith was obtained as accepted stock with rejects still containing some pith when a cone 12" x 3" x 3" and a 1 3/4"-bottom tip was used. It was indicated that a second pass of rejects through the Centri-Cleaner would result in pith freer of fiber than by screening tailings over the Jonsson screen. Possibilities for separating long fiber and pith seemed promising.

Hawaiian bagasse which had been passed through the disc mill at a moisture content of 75 percent was used in trials with both the 12" x 3" x 3" and 12" x 4" x 4" units having 1 3/4"- and 2"-bottom tips, respectively.

In both cases the accepted fraction consisted of pith and long fiber, while rejected material containing shorter fiber and pith was discharged from the bottom. Best results were obtained with the 12" x 3" x 3" unit. Data in Table 10 was obtained in a test run with this unit. In this table also will be found

data that might have been obtained in a second pass of the rejects, assuming that the same conditions of fractionation would have taken place, as during the first pass. Table 11 gives results obtained on analyzing accepted and rejected fractions during this test run.

From these data it is evident that no fractionation of fiber took place since it was equally distributed between the accepted and rejected fractions. On the other hand, the pith material was fractionated to such an extent that 65 percent of total pith was obtained in the accepted fraction. Fiber in the accepted fraction was long and could be easily separated from the pith by screening. Assuming that on passing the rejected fraction through the unit the same percentage of fractionation would have taken place, a second accepted fraction of 24.3 percent would have been obtained with a final rejected fraction from the two passes of 20.7 percent. The total accepted fraction of 79.3 percent could have been screened to produce about 50 percent fiber and 30 percent pith. Adding the fiber fraction after screening to rejected material, a total fiber fraction representing 70.7 percent of the original containing 4.1 percent pith (original basis) would have been obtained. This fiber fraction would have been satisfactory for use in pulping since it would contain about 6 percent pith. The pith fraction would have been relatively fiber-free.

Consistency of accepted fractions is extremely low, 0.155 percent. Inasmuch as consistency of feed must be about 0.25 percent, volume of water to be pumped, screened to separate pith, and filtered to gather pith is much greater than if separation had been made by diluting material from the disc mill to 1.0 percent consistency and screening over the Jonsson screen, followed by filtration to collect pith. From this data it is evident that use of the Centri-Cleaner for separation of bagasse into pith and fiber is not as practical as other methods which were studied.

Dewatering of Pith

Any wet-screening method presents a problem of collecting pith from dilute suspensions flowing from the screen at a consistency of 0.2 to 0.4 percent. Fiber from the Jonsson vibrating flat screen, or Centri-Cleaner, when passed over a drainer having 1/8" holes, drains rapidly to consistencies in the neighborhood of 17 to 20 percent depending on fiber-size characteristics.

Several methods of collecting and dewatering pith were investigated.

Tests with Vibrating Screen

This pilot-plant model NRM-124 vibrating screen (Figure 10) was obtained through a loan agreement with the Link-Belt Company which also cooperated by having two of its representatives visit the laboratory on several occasions to offer suggestions and review operating data.

The unit has a 2' x 4' screening surface. Vibration is induced by high-speed rotation of eccentric weights mounted transversely across the top of the screen. When in operation the eccentric weight system rotates about its center of mass causing the screen frame to move in an elliptical pattern on its spring mounting. Amplitude of vibration can be adjusted by varying the eccentricity of two end weights in relation to eccentricity of central shaft. The NRM-124 screen was driven at 1,750 r.p.m. by a 2-hp. motor.

The wire cloth screen, removable as a unit, was supported in the frame by brackets mounted along the side. Screens used in this test program were 75-, 100-, and 120-mesh. A description of wire size and opening dimensions is given in Table 12.

Dilute pith slurry was fed to the screen from a headbox which provided uniform delivery. A 3" Fairbanks-Morse trash pump was used to deliver pith slurry to headbox from collection tank. The pump was fitted with a recycle connection to the tank in order that a constant but variable feed rate could be obtained.

A preliminary series of runs was made using pith which had previously been dewatered in the rotary screen. These tests were made to study operational features of equipment. Because of previous dewatering, capacity and loss data from these runs were not significant.

A thorough test of dewatering screen required use of pith slurry leaving the Jonsson screen. Therefore, for each dewatering test, it was necessary to carry out a complete Hydrapulper run and Jonsson screening operation. Conditions of bagasse type, Hydrapulper operation, and fiber screening were duplicated, insofar as possible, to reduce variations in dewatering data.

The first four runs were made with pith slurry as delivered from the Jonsson screen at low consistency, 0.17 to 0.28 percent. In anticipation that an increase in capacity and reduction in loss could be achieved by increasing consistency of feed, pith slurry for remaining runs, except run 88, was concentrated by allowing it to settle and decanting off the clear liquid. Some of the soluble and colloidal materials were lost in the decanted liquid. A similar concentration of pith slurry in a factory operation could probably be achieved by any one of several thickening devices.

Flow rate to screen was regulated by a valve in the discharge line from the pump. Flow rate was determined by timing the pump operation and measuring drop in level in feed tank.

During the test series, variations were made in the eccentric weight setting, slope of screening surface, and mesh of screen covering.

Pith discharged from the screen was collected, dried, and weighed. Screen effluent was also collected and analyzed for total solids.

Variables studied during tests were: Slope of screening surface, amplitude of vibration of screen, and rate and consistency of feed. Determination of loss of solids material through the wire and its character, whether soil or fine pith particles, was made. Moisture content of pith collected over the screen was determined in each case. Pertinent data from this test program, tabulated in Table 13, are presented in Figures 11 and 12. It will be noted that at feed consistencies of from 0.17 to 0.46 percent, loss of solids through screen was from 32 to 40 percent. About 85 percent of these solids are composed of pith. From 27 to 34 percent of the actual pith was lost. Assuming that consistency of feed to dewatering screen could be increased to 1 percent or more by use of a settling basin, loss of solid material through screen could be reduced to about 25 percent. These losses of pith are believed to be too high for practical operation.

Table 13 and Figure 12 show relationship between screen capacity and feed consistency. Between 8 to 12 sq. ft. of screen surface/min./lb. of pith are required for consistencies between 0.17 and 0.46 percent. It is evident from Figures 11 and 12 that a 75-mesh screen would be the most practical for use since it showed a considerably higher screening capacity at low consistencies, while losses through the screen were practically the same as those through a 100- and 120-mesh screen.

Dewatered pith coming off the screen, as shown in Table 13, had a solids content of from 5.2 to 6.5 percent, which was quite satisfactory.

Losses of valuable pith material when this screen was used as a dewatering machine were large enough to rule out its use in a commercial installation. Screen capacity also appears to be too low, requiring too large a screening area. Consistency of pith from screen at 5 to 6 percent is quite satisfactory.

Rotary Vacuum Filters, Deckers, Save-Alls

An extended study was made of rates at which pith slurries from the Jonsson screen could be filtered. Data was obtained by use of a small stainless-steel filtration disc having exactly 0.01 sq. ft. filtering area, dressed with a wire of 150 mesh. By dipping the disc into slurries of known composition, at definite depth, for varying lengths of time and under known conditions of vacuum, it was possible to secure data on rate of collection of filtrate, rate of filter cake formation, cake thickness, filter cake moisture, and solids lost in filtrate. This is information required for calculating size of commercial equipment.

Data obtained in testing pith slurries from several varieties of bagasse are presented in Table 14 and in Figures 13 and 14. These data show filtration rate decreases and thickness of cake increases with increases in consistency of slurries. All filtrates contained fine solids to the extent of about 12 percent of total solids in the slurry.

These data were submitted to various manufacturers for estimates on size of machines to filter slurries containing 90 tons o.d. pith/24 hr. It was reported by one company having experience in the pulp industry that filtration rate of pith was about four times that of groundwood. Instead of a 33-percent submergence of rotary filter this company stated that 50 to 60 percent filter submergence would be desirable. Under these circumstances they calculated a filtration rate at 0.4-percent consistency at 10 r.p.m. of 38 g.p.m./sq. ft. filtering surface. On this basis a filter having an effective filtering area of 125 sq. ft. under 5" to 10" vacuum would produce a cake of 14 to 15 percent solids content. It was suggested that if the tank from which slurry was to be pumped to the filter was agitated, and slurry drawn off the upper half of the tank, dirt would settle in the tank, producing a cleaner pith and increasing filtration rate. Dirt might be removed from bottom of the tank intermittently by a sludge pump. It is possible that other filters having similar filtering characteristics might be found.

It was estimated that a decker operating under zero vacuum would require a filter area of between 500 and 1,000 sq. ft. Under these conditions consistency of the cake would be 5 to 6 percent. During tests at The New York School of Forestry, referred to above, a decker, dressed with 40-mesh wire was used to collect pith effluent from the Jonsson screen. Losses of pith from this decker were not known, but were high. The cake on the decker had a consistency of 4 percent. It is probable that the losses of pith through the decker wire would approach the losses from the vibrating screen.

Industrial save-alls were also considered. In this case, losses of pith would be from 25 to 35 percent and the machine would be more expensive.

By Settling

Because of low consistencies of pith slurries obtained on screening treated bagasse, it became desirable to study the settling rate of these slurries. In the study of the dewatering screen, samples of slurries pumped to the screen and samples of effluent from the screen were collected. These samples of known consistency were poured into a 1,000-ml. glass graduated cylinder having internal dimensions of 8.25" high by 3.07" in diameter. After being thoroughly mixed, they were allowed to settle. Line of subsidence was observed and recorded at fixed time intervals.

Settling data are plotted as height of subsidence zone vs. time. Figure 15 shows curves for 5 runs of varying consistency in which Hawaiian bagasse, crop 1950, Laupahoehoe Sugar Company, was used. Pith obtained from this bagasse was of uniform high quality, quite free from fiber. Figure 16 shows 3 runs using slurry from Hawaiian bagasse, variety 8560, which produced pith containing a larger percentage of short fibers. It can be seen that the settling rate at comparable consistencies was faster for poorer quality, denser pith. Figure 16 also gives data obtained on the effluent from the dewatering screen.

Observations during this study indicated that pith suspensions in the range 0.0-to 0.4-percent consistency have the character of independent subsidence where settling is governed by Stoke's Law. Slurries having consistencies 0.4 to 2.7 percent can be classified as being governed by collective subsidence. As noted above, pith slurries as discharged from the Jonsson or flat screen have consistencies between 0.2 to 0.3 percent, while effluents from a vibrating screen or filter have much lower consistencies.

In all settling tests the supernatant liquid remained cloudy, even after prolonged standing. The charge on the suspended colloid was found to be positive. Addition of alum to a pH of 7.0 clarified the liquid.

These data were submitted to the manufacturer of settling equipment who estimated that a 100'-diameter hydro-settling basin would probably handle the slurry from a plant producing 90 tons o.d. pith/day.

Dewatering Press

Pith, as removed from a decker, vibrating screen, or filter, will have a moisture content of from 85 to 95 percent. This

moisture content may be reduced to 60 to 65 percent by pressing. A type of screw press was used commercially in dewatering pith recovered by a save-all from white water produced in an insulating board plant. Screw presses are rather widely used in the cellulose pulp industry for dewatering. It was not possible to carry out a pilot-plant run excepting on one type of dewatering press known as Zenith. The Jackson and Church Company of Saginaw, Michigan, which make this press, cooperated with the laboratory in arranging a test to dewater pith at their Saginaw plant.

The Zenith press consists of a tapered spindle with external flights which carry material to be pressed down through a perforated cylinder and subject it to increasing pressure as it progresses. The spindle itself is perforated to allow some moisture to be discharged through the hollow core. A movable cone fits into the bottom of the cylinder. Air pressure is applied to this cone to maintain a constant pressure on the discharging cake. The cake discharges through the annular space between cone and perforated cylinder.

The press tested was the ZS model, smallest unit produced by Jackson and Church Company. The perforated cylinder is approximately 12" in diameter by 24" in length. Cylinder and spindle have 0.040" perforations backed by a plate having 0.187" perforations on 0.25" centers, staggered. The press is driven by a 220-volt, 3-hp. motor with a normal load of 8.4 amp. A feed chute, 7 1/2" by 8", leads into the side of the press above the perforated cylinder. There are three blades on the spindle opposite the feed chute which carry feed material into pressing section.

Approximately 90 lb. of dry pith were taken to Saginaw for test purposes. This pith, obtained from Hawaiian bagasse, crop of 1950, Laupahoehoe Sugar Company, had been dewatered over the 75-mesh Link-Belt screen.

Three test runs were made with feed consistencies of 6, 20, and 1 1/2 percent. These consistencies were selected to approximate conditions that would exist in a plant, depending upon type of dewatering equipment used. Six percent is the known discharge consistency from a vibrating screen, 20 percent from a vacuum filter, and 1 1/2 percent is the anticipated consistency from a settling tank.

Feed slurries were mixed in 55-gal. drums and fed to the press in buckets. Before each run it was necessary to fill the press. This was done by raising the floating cone up against the cylinder, then feeding the press until the cone was pushed away and pith began to discharge. Operating time was recorded from the time the press was filled until all feed had been added.

During the 6-percent run, it was noted that water was being pressed through the screen in approximately the lower two-thirds of the cylinder. In the 20-percent run, water was pressed out in only the lower third. A jacket was installed around the press prior to the 1 1/2-percent run to prevent loss of water, hence an observation of effective screen area could not be made. However, it is probable that water was escaping throughout the entire screen length. During each run air pressure was adjusted on the floating cone to obtain approximately uniform cake moisture.

In both the 20-percent and 1 1/2-percent runs, some difficulties developed in feeding the slurry. The 20-percent slurry was too bulky to feed uniformly by hand through the small chute and it was not possible to feed the 1 1/2-percent slurry fast enough to keep the press full at all times.

Separate containers were provided to collect the effluent through outside screen and through spindle. These effluents were weighed and sampled. Pith cake was also collected, weighed, and sampled. All samples were brought back to Peoria for solids-content analysis.

Data obtained from the three tests are listed in Table 15. It can be seen that solids content of pith discharge varied from 34.3 percent to 40.4 percent. Pith recovery ranged from 87.2 percent for the 1 1/2-percent run to 99.4 percent for the 20-percent run. Little significance can be attached to capacity data since only one brief test was made at each consistency and feeding technique was not ideal as explained above. However, in pilot-plant operation it should be possible to maintain a discharge rate at least as great as that in the 6-percent run which was 291 lb. pith/hr., o.d.

The Zenith press is an easily operated, efficient unit which should prove satisfactory in dewatering pith. It appeared that the press was operated more effectively when handling slurry at 6 percent or less consistency. Although pressing loss increases with decreasing consistency, it should be possible to recycle effluents to prevent loss of pith from the system.

Jackson and Church Company make two other models of Zenith press. The ZM model has a rated capacity of 3 to 4 times the pilot unit and the ZL model 10 to 16 times. Assuming that the capacity value for the 6-percent run can be duplicated, the ZL press should handle 35 to 55 tons of pith/day.

Separation of Loosened Pith and Fiber in Moist or Dry Conditions

Based on foregoing tests, several methods of processing raw bagasse into high-quality pith and fiber may be visualized. All machines needed in such processing methods are available on the market. Estimates of processing costs indicated that some methods might be practical and economical. Nevertheless, the large amount of water required in processing material in water suspension is objectionable. It introduces problems of water re-use, stream polution, and high pumping charges.

Experience in screening raw bagasse in sugar mills, either in moist condition as it comes from the cane mill, or dry, shows that by use of fine screens a small fraction of pith mixed with dirt, but almost free from fibers, can be obtained. Most pith in raw bagasse is not free, since it is either embedded in rind fibers or attached in chunks to fibrovascular bundles. It was desirable to determine to what extent pith could be removed from disc-mill-treated bagasse by dry screening.

Tests were made first with a small No. 11 Rotex screen, available at the laboratory. Bagasse used was steamed at a few lb. pressure in presence of 3 parts of water to thoroughly wet fiber and pith. It was then passed through the double-disc mill at the laboratory using devil-tooth plates at a setting of 0.30". Treated material was dried in a tunnel drier, lumps were broken up by hand, and material was screened over a 10-mesh screen. The fraction passing the 10-mesh screen was rescreened over a 16-mesh screen. The fraction passing this screen proved to be a good grade of pith containing only a small amount of short fiber. Material retained on both screens contained a considerable proportion of pith and short fiber.

This test was so promising that arrangements were made with the Orville Simpson Company, Cincinnati, Ohio, to carry out some tests and submit a recommendation for industrial units capable of handling 100 tons o.d. bagasse/day. For the purpose of these tests Puerto Rican bagasse was treated in the disc mill, dried, and shipped to Orville Simpson Company. Results of their tests are reported in Table 16. Various fractions of material obtained in their tests were analyzed in Peoria for pith and fiber content. For paper manufacture it is desirable to use fiber as free from pith as possible. The fiber obtained in run No. 3 was the best in this respect, but the grade of pith was poorest, and feed rate was low.

Screens used by Orville Simpson Company were made of square-mesh wire. Believing that this type of screen might be more subject to blinding and stapling than screens made from perforated plate, tests were made at Peoria using plate perforated

with various sizes of round holes. It was found that a good separation of fiber and pith could be made by screening the disc-milled, dried bagasse over three screens in series having holes with diameters of 0.436", 0.156", and 0.095", respectively. Material retained on each of the three screens was combined to make the fiber fraction. Material passing the screen with 0.095"-diameter holes comprised the pith fraction. Table 17 gives results obtained by screening various samples of bagasse that had been disc-milled and dried.

These results were discussed with Orville Simpson Company which stated that it would be practical to screen in this manner, and submitted estimates for commercial screen installations.

Recently, an opportunity was afforded to make a commercial trial of this screening process at a sugar mill. Bagasse containing 49 percent moisture was passed through a disc mill, dried, and screened over the series of three screens. It was found that balls used with the square-mesh screens to prevent blinding were not effective with the perforated plate screens because of their rigidity. By attaching small chains so that they would rub over the surface of screens having 0.436"- and 0.156"-diameter holes, blinding was effectively stopped. This test showed conclusively that pith could be loosened from fiber by passing moist bagasse through a disc mill, and that by use of selected screens dried material could be fractionated to give good quality pith and fiber.

If the operation of separating bagasse into pith and fiber were to be carried out at a sugar mill, which would seem to be the most suitable location, it might be desirable in certain cases to avoid the drying step and thus obtain moist fractions of pith and fiber. In order to determine if such a scheme might be feasible, tests were carried out using the three screens to separate disc-milled fiber which had been reduced to a moisture content of 50 percent by hydraulic pressure. In the sugar mill this could be done by passing material coming from the disc mill through a set of sugar-mill rolls. The results of these screening tests are given in Table 18.

Yields of fiber and pith obtained by this moist screening method are comparable with those obtained on screening dry material. Both fiber and pith fractions seemed to be of slightly better quality than obtained by screening dry material. Rate of screening was, however, only about 45 percent of that obtained when screening dry material.

Drying of Bagasse, Fiber, and Pith

Depending on the end use of separated fiber and pith, either or both might have to be dried. At the present time several sugar

mills in the United States use rotary driers for drying bagasse from the cane mill for producing chicken litter, mulch, and other industrial products. These driers have proven satisfactory although in those cases where information on operations could be obtained, it was evident that a considerable loss of fine material was taking place. This was believed to be due to presence of sugar, largely held in pith cells, which caramelized at the high temperature causing pith to burn, and also to loss of material from cyclones, due to the use of excessive volumes of air. In spite of these losses the drying operation is proving profitable.

After discussions with several companies manufacturing driers suitable for the purpose, Combustion Engineering-Superheater, Inc. and General American Transportation Company, both having pilot plants in Chicago, kindly offered to carry on cooperative tests in their plants.

Flash Drying

This test was carried out in cooperation with Combustion Engineering-Superheater, Inc. for the purpose of determining: (1) Whether the flash-drier principle would be suitable for drying pith economically, and (2) optimum operating conditions and capacity of the pilot plant for drying pith so that a suitably sized commercial unit could be designed.

Flash drying is the practical instantaneous removal of moisture from materials by application of heat in a turbulent stream of hot air. This is accomplished by uniformly adding wet material into a screw conveyor which breaks up wet cake and lumps and discharges them into a cage mill. At the same time hot gases of combustion are discharged into the mill. A high-speed fan forces this mixture upward into a cyclone from which dry material is discharged into a loading spout, and fines, if present, are discharged from the stack.

Separated Hawaiian bagasse pith containing about 60 percent moisture was shipped from Peoria for the test. The pith was readily dried from 60 to 12 percent moisture with practically no loss of fines. Dry pith was discharged as a granular product free from lumps or balls, which are generally found in the dry product when the wet pith is dried in trays. Drying was carried out with little or no change in particle size or color. Maximum inlet temperature was 1,290° F. and outlet temperature 360° F. Highest temperature reached in the product was 150° F. Drying did not change original absorption capacity of pith. The drying system would occupy a minimum amount of floor space. Additional moisture could be removed from material if the hot dried product were blown from the drier cyclone to a molasses mixer.

Rotary Drying

These tests were carried out in the Research and Development Laboratory, General American Transportation Company, using pith of about 60 percent moisture, shipped from Peoria.

Pith was satisfactorily dried in the 1' by 8' pilot model Louisville Type H parallel-current rotary drier. The Type H drier is designed with circumferential and radial baffles on interior of cylinder. These baffles retard forward movement so that material being dried is carried forward only by a fan located between drier and cyclone. The drier is designed to treat materials of low-bulk density, such as wood flour, and is operated similar to a flash drier because contact time is short and temperature and capacity high. Maximum entering temperature of 1,300° F. was used without obtaining any noticeable burning of pith. Outlet temperature was 245° F. and maximum temperature noted in product was 142° F. when material was dried from 60-to 12-percent moisture content. Pith was discharged in a granular, loose, free-flowing form.

Separated fiber could not be satisfactorily dried in the Type H drier because air velocity was not high enough to lift and carry wet fiber forward. As a result, fiber collected on baffles and eventually burned. Tests were then made with the standard parallel-current rotary drier with no baffles, which showed that fiber could be satisfactorily dried from a moisture content of 45 to 10 percent. Rate of travel in this type of drier was slow and inlet temperature had to be kept below 850° F. to avoid burning. Inlet temperatures of 800° F. and outlet temperatures of 230° F. gave a satisfactory product.

It is probable that a mixture of bagasse pith and fiber has different drying characteristics than either separated pith or fiber.

A summary of estimated requirements to dry pith, fiber, or bagasse is given in Table 19.

SELECTION OF PROCESS OF SEPARATION INFLUENCED BY INDUSTRIAL FACTORS

Based on these studies it is possible to develop flowsheets for several different processes using available machinery. However, other factors must be taken into account. If the process is to be operated at a sugar mill, moist bagasse will be available. This can be processed best by use of a disc or similar mill. If processed elsewhere, stored bagasse will be used and

must be wetted before processing. For this purpose the pulper seems best suited. In any case, it will be desirable to select a process requiring minimum use of water and requiring as few steps as possible.

Separation Process Carried Out at Sugar Mill

There appear to be a number of advantages in making separation at the sugar mill. Conveyors for handling large tonnages of bagasse are already installed. Generally, a surplus of bagasse exists or could exist. Some bagasse is now being screened to provide bagaccia for use in filtering muds. Some sugar mills in this country are presently drying and screening some or all bagasse in rotary driers to produce mulch, litter, and other products for sale. Losses of sugar in bagasse are increasing due to dirt and trash brought to mill with mechanically harvested cane. Blackstrap molasses is produced concurrently with sugar and bagasse. Baling equipment is located in many of the sugar mills. The outstanding disadvantages are that the grinding season is very short, in some cases not even 90 days, and capital investment and other charges against such operating expenses are much higher than with operations covering 300 days.

The process best suited for installation at the sugar mill is outlined in Flowsheet 1, Figure 17, which shows that bagasse as it comes from the cane mill--at a moisture content of 48 to 50 percent--is sprinkled on a conveyor with showers of fresh water to increase moisture content to 75 percent. This means that a weight of water equal to wet weight of bagasse is added. The material is conveyed to a disc mill, equipped with a forced feeding device and waveline plates. Bagasse, from which no free water drains, is conveyed from the disc mill to a set of sugar-mill rolls. Passage through this press reduces moisture content to 50 percent. The extracted solution contains two-thirds of the soluble material including sugars left in bagasse by the cane mill. It will be necessary to provide a device for feeding the set of rolls so that the disc-milled bagasse can be fed in a uniformly thick mat across the face of the rolls. Material from the roll press is then ready for drying, followed by screening (Case 1 A), or may be screened at 50-percent moisture content (Case 2 A, 3 A). For the purpose of complete discussion Flowsheet 1 also gives indicated uses of separated fiber and pith.

This process permits <u>possible recovery of additional sugar</u>. The amount of sugar left in bagasse is dependent on many local conditions, such as cane variety, purity of juices, milling setup, and operation of the sugarhouse. In countries where mechanical harvesting of cane is being practiced, amount of

sugar left in the bagasse, in general, has shown a gradual increase. For example, statistics show that in Louisiana the amount of available sugar left in the bagasse increased rather steadily from about 8.5 percent in 1939 to 10 percent in 1952 (10).

It seems obvious that improvements in extraction might reduce losses of sugar in bagasse. The disc mill greatly changes the physical condition of bagasse as it comes from the cane mill. Pith is now in small particles and is no longer embedded in fiber bundles. It is believed that this will make possible a better extraction. The same result would not be expected if only another sugar-mill roll was added to the cane mill to increase extraction.

Bagasse, as it is produced on a 50-percent moisture basis, may contain from about 2 to 5 percent sugar, or double this amount on an o.d. basis. In addition to sugars (sucrose and glucose), nonsugars, nitrogenous compounds, other soluble material, and waxes are present in moist bagasse. Extraction of soluble materials from bagasse results in a sugar solution of low purity. Thus the proportion of molasses resulting from this solution would be larger than that from cane juice. Nevertheless, if separation of bagasse into pith and fiber is to be undertaken at a sugar mill, recovery of more sugar and molasses from cane deserves serious consideration, not only because of desirability of lowering costs of over-all operations but also because if an additional sugar-mill roll is installed to dehydrate disc-milled bagasse the solution expressed will contain two-thirds of the sugars and can be returned to the sugar mill.

As an example of what this might mean, a test was made at one of the mills to determine the character of the extract from bagasse under these conditions. Bagasse fresh from the cane mill was treated with an equal weight of water, to raise its moisture content to 75 to 80 percent. Samples were then subjected to a pressure of 2,000 p.s.i. to bring moisture content of bagasse back to the original 50 percent. Volume of extract was measured and Brix (by refractometer), polarization, and apparent purity determined. Results of tests are given in Table 20. Bagasse had a sucrose content of 3.5 percent. If it be assumed that two-thirds of the sucrose would be extracted, 46.7 lb. of sucrose/ton of 50-percent bagasse would be produced. An average of the tests showed that 51.2 lb./ton were extracted.

From the standpoint of sugar-mill operation, having installed a process for pith and fiber separation, bagasse coming from the cane mill would be sprayed with an equal weight of fresh

water and the added water would be extracted by the rolls used for the separation process. This solution now containing juice of 70-percent purity or better would be returned to the cane mill for countercurrent extraction, instead of the fresh water usually added. Its volume is now equal substantially to that of the fresh water normally used, and there would be no more effluent from the sugar mill than before. Under these conditions additional expense of operation would be in evaporation and crystallization of sugar and handling of molasses. Recovered sugar and molasses would help pay the costs of the pith-fiber separation process. Assuming that half the sucrose extracted could be obtained as crystalline sugar, with sugar at 5 cents/lb., each ton of 50-percent bagasse would yield $1.17 worth of sugar, together with a quantity of molasses. A ton of o.d. bagasse would yield $2.34 additional revenue as sugar. A mill producing 15,000 tons of o.d. bagasse/season would recover sugar to the value of $35,100 which would amortize the cost of the additional set of press rolls the first year.

Costs of Separation

Costs of separating bagasse into fiber and pith at the sugar mill, according to the three schemes--1 A, 2 A, and 3 A, shown in Figure 17--were estimated on the basis of 100 tons o.d. bagasse/day as follows:

Capital Costs, see Table 21. These do not take into account cost of conveyors, length and number of which would vary depending on local conditions, nor do they include cyclones and ducts. It will be noted that there is very little difference between capital costs of the three schemes.

Fuel value bagasse, $2.50/o.d. ton

Gas as fuel, $0.16 2/3/thousand cubic feet of 1,000 B.t.u.

Electric power, $0.01/kw. hr.

Direct labor, $1.00/hr., including social security

Supervision, 9 percent of direct labor

Maintenance, 4 percent capital costs, operation 100, 180, and 300 days

Equipment supplies, 15 percent maintenance

Depreciation, 5 percent capital cost, operation 100, 180, and 300 days

Taxes and Insurance, 2 percent capital cost, operation 100, 180, and 300 days

Overhead, 50 percent direct labor, supervision, and maintenance

Yield, 90 percent bagasse processed, giving 68.4 percent fiber and 21.6 percent pith

Baling dry bagasse fiber, $2.50/o.d. ton fiber

Mixing molasses with pith and pelleting, $2.50/o.d. pith

Credit, $1.00/ton o.d. bagasse processed for sugar recovered.

In Cases 2 A and 3 A, cost of processing pith or fiber to be returned to the boilers as fuel was charged against the cost of producing dry fiber or pith.

It was found that the capital cost of the rotary drier for drying pith was considerably lower than that of the flash drier.

Estimated operating costs/ton o.d. bagasse for Cases 1 A, 2 A, and 3 A are given in Tables 22, 23, and 24, respectively. These show the effect of length of operating season on costs. The shorter the operating season the higher the fixed charges and maintenance costs. Lowest costs of operation result in Case 2 A, because fuel, power, and fixed charges are lower. Highest costs result in Case 3 A where fiber is returned wet to boilers. This is due to the fact that all processing charges for handling fiber are included in pith costs.

If fiber and pith can be used for purposes other than fuel Case 1 A is to be preferred. Where bagasse surplus to fuel requirements of the sugar mill is processed, costs of dry pith and fiber would be $2.50 less than shown in the totals.

Separation Process Carried Out on Stored Baled Bagasse

Capital investment in such manufacturing operations as those for paper, paperboard, or building board is extremely high as these operations depend largely on continuous processing throughout the entire year. When a raw material such as bagasse, produced only seasonally, is used it must be stored. Methods have been developed for satisfactory commercial storage of bagasse which is baled wet and stored under controlled conditions in large outdoor piles. Bagasse dries out normally over a period of about 6 mo., due largely to heat generated by fermentation processes. After drying, bales are dense and rather difficult to disintegrate and the bagasse will not wet easily.

At the present time all companies using bagasse to produce paper, paperboard, or building-board products use stored bagasse. It would be natural to expect that any separation of stored bagasse into pith and fiber would be carried on by the user. In considering processes for fiber and pith separation first attention should

be directed to means for wetting bagasse. Studies here reported, as well as commercial practice, indicate adaptability of the Hydrapulper for this purpose. Three processes using the Hydrapulper, designated as Cases 1 B, 2 B, and 3 B, will be discussed.

Generally, a bale breaker is required to disintegrate the bale into small pieces. Since the process of fermentation has a tendency to loosen some of the pith from fiber, bagasse from the bale breaker can be passed over a screen to advantage. Dry pith recovered from the screen can be added to the moist pith obtained later in the process. Estimates of capital costs of bale breakers, screens, and cyclones needed for this part of the operation, as well as operating costs, have not been included in this report.

One method of making the pith fiber separation using the Hydrapulper (1 B, Figure 18) would consist of adding screened bagasse batchwise to a Hydrapulper having a solid plate, and containing the required amount of water to treat bagasse at about 8-percent consistency. At the end of the treating period (about 20 to 30 min.), when pith has been satisfactorily loosened from fiber, the outlet valve is opened while the pulper rotor is in motion and contents of the pulper are washed into a stock chest. Water is added to the chest to make the consistency of the slurry 1 percent. Slurry is pumped to a battery of Jonsson screens. Fiber coming from the screens is allowed to drain to about 18- to 20-percent consistency and may be used directly for the manufacture of paper, paperboard, or other cellulose pulps. The pith fraction or effluent from the primary screen is passed to a second Jonsson screen to remove coarse fiber, which is added to fiber from the primary screen. Pith is filtered from slurry on a vacuum filter and dewatered to about 40-percent dry content by passage through a screw press. Filtrate is collected in a storage chest and recycled as process water. Settled dirt and mud in the chest is removed by a sludge pump.

In Case 2 B, Figure 19, the Hydrapulper is supplied with a perforated extraction plate. Screened bagasse is added batchwise to the machine filled with water and treated until pith is satisfactorily loosened. Then, the outlet valve under the extraction plate is opened and, while the rotor is turning, water is added to the pulper at rates at which it is drained. The effluent is collected in a chest. This operation lasts for about 2 min. and washes pith from the fiber. The valve is closed, water is added to the pulper, and the outlet valve above the extraction plate is opened so that the fiber can be washed onto a drainer. The slurry of pith in the chest is passed over a Jonsson screen to recover coarse fiber; pith is collected on a vacuum filter, and dewatered in a screw press. The filtrate is collected in a chest and recycled.

Both of these processes require pumping of large volumes of water, 25,000 gal./ton o.d. bagasse in Case 1 B and 17,000 gal./ton in Case 2 B. In turn, fiber obtained in both processes contains about 80 percent moisture and pith, 60 percent. Case 3 B, Figure 20, requires 8,000 gal. water/ton o.d. bagasse and produces fiber and pith at 50-percent moisture content. This process would be suitable if pith is to be burned or particularly if it is to be dried for use as an absorbent. Case 3 B uses a Hydrapulper with an extraction plate having large enough holes so that all pith and fiber will pass through. The machine is used as a means of wetting bagasse in a continuous operation, that is, screened bagasse and water are added at rates at which they are drawn off as slurry of about 2.5-percent consistency. Slurry is drained and the mass passed through a disc refiner, from thence through a set of sugar-mill rolls, and screened moist as in Case 2 A and 3 A. Drained water is collected in a chest and recycled as process water. If pith is to be dried, drying costs will be approximately $2.50/o.d. ton pith, based on use of a rotary Type H drier with oil at $0.06/gal., power at $0.01/kw. hr., and labor at $1.00/hr.

Costs of Separation

Estimated capital costs of equipment required for the three processes designed for treating stored bagasse are given in Table 25. It will be noted that capital costs decrease as amount of water required in processes decreases, and costs and hp. requirements are least in Case 3 B.

Operating costs are calculated on the same basis as for Cases 1 A, 2 A, and 3 A with the exception that stored bagasse is charged into process at $9.90/o.d. ton. This bagasse cost is estimated by Keller (11) as follows:

Purchase price of bagasse	$2.50 o.d. ton
Baling, stacking, and covering bagasse in field	6.00 o.d. ton
Loading costs and storage to railroad cars	0.50
Total cost at sugar mill	$9.00 o.d. ton bagasse

During storage a loss of fiber of at least 10 percent occurs, due to fermentation, equivalent to $0.90/o.d. ton, making a total cost from storage of $9.90/o.d. ton. Transportation costs from sugar mill to factory of the user are not included.

Operating costs for the three different processes are given in Table 26. Costs are almost the same for Cases 2 B and 3 B and both are lower than for Case 1 B. Operation according to

Case 3 B is therefore preferable because capital costs are lowest and fiber and pith both are obtained at low-moisture content of 50 percent. It will be noted that if no use can be found for pith, fiber will cost $18.13/o.d. ton. If use can be found for dry pith at a cost of $13.78 plus $2.50 drying cost, or a total of $16.28/o.d. ton, fiber at 50-percent moisture content will cost $13.78/o.d. ton.

Separation at the Sugar Mill Most Economical

It is obvious from these cost analyses that separation at the sugar mill will be more economical and profitable to both the sugar mill and the user. If fiber is produced at the sugar mill it will be in its best condition for use since it will be dry and will suffer no losses due to fermentation in storage. To costs for producing fiber must be added a charge for storage, estimated at $4.00/o.d. ton. In addition, there must be added profit and transportation costs from the sugar mill to the user.

USES FOR WHOLE BAGASSE, PITH-FREE FIBER, AND PITH

Whole Bagasse

Only a portion of bagasse produced is waste material, in the sense that its disposal involves an expense. Bagasse is a high bulk material, having a weight, as produced, of about 10 lb./cu. ft., and is ordinarily conveyed directly to boilers or to loose-storage pile, which serves as a standby for fuel when the cane mill is not operating. Bagasse is a good low-grade fuel. With present boiler design, there is very often more bagasse produced than is needed for all sugarhouse fuel requirements. If no other use is made of surplus bagasse, it is used in furnaces, resulting in lower efficiency, and greater expense, or it is stored in piles which are later burned. Gastrock and Lynch (12) give a chart for calculating fuel value of bagasse in terms of oil, gas, or coal. Calculations take into account relative calorific values, boiler efficiencies, and unit fuel costs. One ton (2,000 lb.) of bagasse, 50-percent moisture content, has a fuel value of 6 million B.t.u. equivalent to 6,000 cu. ft. of 1,000 B.t.u. gas, or one barrel of fuel oil (42 gal.). Dry bagasse would have twice this fuel value. In some places bagasse is baled for use as fuel after the grinding season. During storage its fuel value increases due to loss of moisture. In Java (13) briquettes were made from bagasse to supply fuel for cooking and other purposes.

Cost of fuel to replace bagasse in sugarhouse operation will vary widely depending on location and availability and cost of fuel. Louisiana is particularly favored with low-cost gas and oil, and this may have been one reason why it was possible to start a successful industry based on bagasse as raw material. On the other hand, gas and oil as fuels are much to be preferred in sugarhouse operation, and no sugarhouse that has used either of these fuels will of its own choice return to use of bagasse for fuel.

In making economic surveys for location of industries based on use of bagasse, the question of fuel requirements deserve most careful consideration.

Efforts to make valuable products from bagasse have continued for more than a century. Results of all this work are meager indeed, and, even now, less than 1 million short tons of bagasse, dry basis, are used annually in the world for any purpose other than fuel at the sugar mill.

Building Materials

Building material products are now made from whole bagasse in Louisiana, Hawaii, Australia, and, before the war, in Formosa and in England. Technology of these operations is now well understood. Several companies are prepared to build mills for this type of manufacture, so that its establishment in still other countries depends only on solving sales and economic problems.

Mulch and Litter

In Louisiana and Florida, bagasse is processed into chicken litter, and mulch to replace sphagnum moss, a business that is not only proving profitable, but also shows increasing sales volume year by year. For this purpose bagasse as it is produced is dried, using rotary driers; screened to remove as much pith, fine fiber, and dirt as possible; and baled. In some mills moist bagasse is also screened before drying. The dried material then is passed through a coarse hammer mill to loosen more pith before final screening. It is possible to operate such a plant after the grinding season by using baled, stored bagasse. Material prepared from fresh bagasse is brighter in color, less friable, and cleaner than that made from stored bagasse.

Paper Manufacture

Efforts to manufacture paper from whole bagasse began a century ago. Of the many companies started, none operated for any length of time. In general, failures can be attributed to a lack of appreciation of technological and economic factors involved. In some cases plants were too small for economical operation; in

others, handling costs and imperfect methods of storing bagasse were at fault. Generally the goal was to manufacture papers for which the material was not suited, by methods intended for pulping wood. In the late 1930's interest revived in the possibility of making paper from bagasse. By this time the problem of storing bagasse was solved, and methods for economical baling and handling had been developed. A better understanding of the technology of pulp manufacture had been gained in many laboratories.

At the present time, at least 11 paper mills are known to be producing pulp from bagasse. Most of these mills blend bagasse pulp with wood or bamboo pulps to make a variety of papers or boards. Three mills, in the Argentine, the Philippines, and India, use the Cellulose Development Corporation process to make bleached pulp, and another is beginning operations in Brazil. Two mills in Peru use a modified kraft process, making board and a wide variety of papers, including newsprint for the Peru market. A mill in Formosa is making unbleached and bleached bagasse pulp by the neutral sulfite process. Two small mills in the Argentine are making board from soda-process pulp, and another in Columbia from lime-process pulp. A new mill has started in Mexico producing pulps and paper by the mechano-chemical process. A paper mill owned by a Louisiana sugar company has recently started operation, using a patented process for pulping.

In all these mills, with the possible exception of board mills in Colombia and Argentina, some or all of the pith is removed from bagasse before pulping.

Pith-Free Fiber

Chief commercial use for depithed fiber is in paper and board industries. Objections to presence of pith in the manufacture of paper have been recounted. Advantages that are obtained in the use of pith-free fiber were demonstrated by trials at Forest Products Laboratory (14) and New York School of Forestry (15). In addition, Cia. San Cristobal, S.A., Mexico, D. F., is manufacturing high-grade paper and board products by the mechano-chemical process, using depithed bagasse. This depithing operation is based on principles discussed in this report but machines used are different and quite simple in design.

Several companies have expressed dissatisfaction with using bagasse containing pith left with fiber by dry-screening methods and are seeking methods which will produce pith-free fiber.

As an example of the effect of pith on paper-machine operation, a pilot-plant run at the New York School of Forestry to produce

corrugating pulp from whole bagasse showed that it was so slow draining that it would not run on the paper machine. Only after passing pulp over deckers to remove about 8.5 percent fines material, could a satisfactory corrugating medium be made from it. On the other hand, a corrugating medium superior to commercial medium was easily made from depithed fiber.

Yields of cellulose pulps from depithed fiber are higher than from whole bagasse and cost of chemicals for pulping is lower. Not taking into account this lower chemical cost, nor the considerably higher quality of the pulps made from depithed fiber, it is possible to make a comparison of costs of different pulps in terms of raw fiber. These cost comparisons are presented in Table 27. The heading of this table gives the assumed conditions. It is evident that, because of higher yield of pulp from depithed fiber in Cases 1 A and 2 A, cost of raw fiber is less than when whole bagasse is used. In Case 3 B, using the Hydrapulper, costs of raw fiber are higher than when whole bagasse is pulped.

It should be clear that use must be found for pith that will at least defray expense of separation. Spread between costs shown for Cases 1 A and 2 A and whole bagasse indicate there is a possibility of competing with whole bagasse on a reasonable profit basis. For example, there is a spread of $8.00/o.d. ton in costs of bleached pulp when depithed fiber (Case 1 A) is used, as compared with whole bagasse. Cost of $9.90/o.d. ton for whole bagasse includes a small profit of $0.50 to $1.00/o.d. ton.

In manufacture of heat- and sound-insulating building materials, a considerable amount of pith in stored bagasse is lost to the sewer. It is probable that products of this type, if made from depithed fiber, would be of improved quality. Experience in manufacture of hardboard indicates that a very free-draining fiber is required. Pith-free bagasse fiber would be better on this account than whole bagasse for manufacture of hardboard.

Reference has been made to the large use of bagasse for chicken litter. It is necessary to prepare a product free from dust for this market. It is possible that depithed bagasse fiber might serve this market as well or better than the present material.

Pith

Cost analyses show that pith-free fiber can be prepared best at the sugar mill during the grinding season. If an excess of bagasse for fuel exists, pith can replace some fiber used for

fuel, with a lowering of cost of $2.50/ton of fiber. If a better market than fuel can be found for pith, then the sugar mill is in a position to benefit still further.

It has already been indicated that such a market exists in using pith as an absorbent for molasses to prepare cattle feed (5). The NURB has continued to investigate this subject, with the result that a method for determining absorption capacity of pith or other feed ingredients has been reported (16). A comparison of relative absorption capacity of wet and dry separated pith and other feed ingredients is given in Table 28. It will be noted that absorption capacity of commercially separated pith is two-thirds to one-half that of wet separated pith, while the capacity of common feed ingredients is from one-third to one-half the same value. A mixture of 30 percent wet separated pith and 70 percent 80°-Brix molasses will not cake in a humid climate on standing, while a mixture of this same proportion of molasses with commercially screened pith will cake. Pilot-plant studies have shown that this mixture can be pelleted, using commercial machines.

Blackstrap molasses and bagasse are the major byproducts of cane-sugar manufacture and each is produced in almost the same amount when cane is ground for sugar extraction. While bagasse always has had a use as fuel, there have been times when blackstrap molasses in some areas had no use. Price of molasses always has been pegged to that of alcohol, and has fluctuated very widely. The latest U. S. Department of Agriculture report on the molasses situation (17) states that molasses prices stood at a record high (New Orleans-wholesale) of 34.5 cents per gal. January 1951. They declined to 9.0 cents in the same market November 1952, and in October 1953 stood at 11.0 cents. Abrupt decline in prices in November 1952 was due to a reduction of Cuban-asking price to 4.5 cents (6.5 cents delivered) for molasses entering into alcohol production. With increased manufacture of synthetic alcohol and closing down in the fall of 1953 of synthetic rubber plants using alcohol, the future for molasses in this market is not bright. From the standpoint of the sugar industry it is extremely important to divorce the molasses market and molasses prices from effects of conditions in the alcohol market. The report cited suggests that conditions for this are the brightest in history.

It has been repeatedly emphasized that the highest price market for molasses is in feeds. Use of molasses in feeding in the United States has steadily increased since 1945. At the present time a large number of authorities on animal feeding are investigating use of roughages, molasses, urea or ammonium salts, and necessary feed supplements for fattening, finishing, and feeding of cattle. For example, very large tonnages of ground corncobs are being fed in such rations. Much study is being devoted to the digestive action of rumen bacteria in making it possible for

the animal to gain energy from carbohydrates, cellulose, and pentosans, in low-grade roughages. Molasses is evidently an important ingredient in promoting this action. It is stated that one-third of protein requirement of the animal may be supplied in such feed by urea, or ammonium salts. Molasses may be ammoniated and urea can be dissolved in molasses. Other feed ingredients such as minerals, vitamins, and antibiotics are available in the chemical markets, but the remainder of protein requirement must be supplied from vegetable sources, generally oilseed meals.

Market surveys have indicated that there is a tremendous potential for molasses as feed in the United States. Merchandising of liquid molasses to the small feeder, or farmer, particularly in the Northern States, is difficult. Molasses in some dry form is desired. Use of pith for this purpose would appear to be practical. Much interest has been expressed in this development by commercial mixed-feed manufacturers and others, since there appears to be an increasing demand for high-molasses feeds.

Use of pith as an absorbent for nitroglycerine for manufacture of explosives was established many years ago. Presently the pith and fine-fiber mixture obtained on screening dry bagasse is used for this purpose. More highly purified pith made possible by developments described would suit this market even better. According to all available data, pith separated by the wet process is the most absorbent organic material which might be available to commerce.

SEPARATION PROCESS APPLIED TO OTHER MATERIALS

Two other materials have been subjected to pith and fiber separation. Corn stover was treated by Process 2 A. The stover was from the 1950 crop, variety U. S. 13, harvested immediately after the corn was picked. It contained most of the husks and some leaves. The dry stover chopped in a silage cutter to lengths of 2" to 3" was treated in the autoclave, passed through the disc mill, dewatered to 50 percent moisture, and screened in moist condition over the set of rotary screens. Results of two tests gave average yields of 62.5 percent fiber, 16.25 percent pith, with dirt and loss of 21.2 percent. It will be noted that a higher percentage of dirt and loss was experienced than with bagasse. Amount of fiber obtained compared favorably with that from bagasse, and quality of pulp from this fiber would compare well with that made from pith-free bagasse fiber. Pith obtained from cornstalks compared favorably in absorption capacity with that from bagasse. If a practical, low-cost method for collecting and storing cornstalks could be worked out, the pith-separation method would go a long way towards

making cornstalks a raw material for high-grade paper. At the same time, pith could be produced for mixed-feed and other industries in the Central States.

At the request of the Belgian Government, some work was carried on in Peoria on pulping of papyrus from the Belgian Congo. It was found that the Hydrapulper method gave a good separation of fiber and pith. In this case, yield of fiber was 45 percent and pith, 45 percent. These studies indicate the wide applicability of processes developed to convert many pith-bearing plants into high-quality industrial products.

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Table 1.-Proximate analyses of various types of bagasse

NRRL no.	Material	Moisture	Ash	Lignin	Pentosans	Extractives in			Cross and Bevan cellulose				
						Hot water	Alcohol benzene	1% NaOH	C and B cellulose		Alpha as run		Alpha-basis original ash- and pentosan-free
									Ash-free	Pentosans in	Ash-free	Pentosans in	
		%	%	%	%	%	%	%	%	%	%	%	%
1267	Louisiana whole bagasse - stored (Lockport - 1941)	4.1	2.9	21.3	29.4	4.0	1.7	32.9	58.4	29.3	67.2	6.1	36.8
1267	Louisiana bagasse fiber - stored (Lockport - 1941)	6.8	2.0	20.7	30.0	2.4	1.6	28.4	61.4	31.7	70.0	10.0	38.7
1267	Louisiana bagasse pith - stored (Lockport - 1941)	12.2	4.6	21.3	29.9	3.1	1.7	36.1	54.6	30.3	62.8	5.7	32.3
1740	Louisiana whole bagasse - fresh (Houma - 1941)	4.9	2.4	18.9	30.0	8.8	6.0	35.9	53.3	27.9	67.3	7.0	33.4
1740	Louisiana bagasse fiber - fresh (Houma - 1941)	9.7	2.2	19.9	32.5	3.4	2.0	30.5	59.0	29.6	67.7	8.1	36.7
1740	Louisiana bagasse pith - fresh (Houma - 1941)	8.7	6.3	18.0	30.7	3.4	2.9	36.2	52.5	28.7	62.4	6.6	30.6
7892	Florida whole bagasse - fresh - dry-screened (Clewiston - 1948)	7.3	2.2	18.1	27.9	11.2	10.8	39.9	52.0	26.9	68.0	4.7	33.7
7892	Florida bagasse fiber - fresh (Clewiston - 1948)	7.2	2.0	19.1	30.9	4.5	2.6	31.2	60.4	29.0	67.2	4.5	38.8

--Continued

Table 1.-Proximate analyses of various types of bagasse--Continued

NRRL no.	Material	Moisture	Ash	Lignin	Pentosans	Extractives in: Hot water	Extractives in: Alcohol benzene	Extractives in: 1% NaOH	Cross and Bevan cellulose: C and B cellulose: Ash-free	C and B cellulose: Pentosans in	Alpha as run: Ash-free	Alpha as run: Pentosans in	Alpha-basis: original ash- and pentosan-free
		%	%	%	%	%	%	%	%	%	%	%	%
7892	Florida bagasse pith - fresh (Clewiston - 1948)	8.9	3.4	18.2	31.4	4.6	2.5	35.0	53.9	26.2	63.4	4.0	32.8
9940	Florida whole bagasse - variety Cl. 41-223 (Clewiston - 1952)	8.6	1.0	18.2	26.6	15.1	7.0	40.7	48.0	28.1	66.9	4.7	30.6
9941	Florida whole bagasse - variety F. 31-436 (Clewiston - 1952)	10.1	1.6	16.4	27.4	15.5	6.4	43.2	48.8	32.7	66.5	5.3	30.8
9942	Florida whole bagasse - variety F. 31-962 (Clewiston - 1952)	10.5	2.2	18.6	28.7	9.8	8.0	40.0	49.0	26.5	67.7	5.2	31.5
9992	Hawaiian whole bagasse - variety 8560 (1952)	13.2	5.4	21.3	27.7	5.7	3.2	33.9	50.2	27.4	69.6	8.8	31.8
9992	Hawaiian bagasse fiber - variety 8560 (1952)	5.6	2.0	21.1	30.7	2.4	3.6	28.8	56.0	28.8	73.4	10.4	38.3
9992	Hawaiian bagasse pith - variety 8560 (1952)	7.1	3.3	20.0	33.0	1.5	2.1	30.8	53.5	29.7	62.7	6.7	31.5
9333	Hawaiian whole bagasse (Laupahoehoe Sugar Co.)	8.0	1.9	22.5	31.2	3.4	2.1	31.4	55.4	27.7	72.5	8.3	34.3
9573	Hawaiian whole bagasse - variety 1933 (Ewa Plantation)	7.7	2.6	19.3	31.3	4.0	3.6	31.3	55.0	33.4	62.6	8.2	31.6

Table 1.--Proximate analyses of various types of bagasse--Continued

NRRL no.	Material	Moisture	Ash	Lignin	Pentosans	Extractives in: Hot water	Extractives in: Alcohol benzene	Extractives in: 1% NaOH	Cross and Bevan cellulose: C and B cellulose: Ash-free	C and B cellulose: Pentosans in	Alpha as run: Ash-free	Alpha as run: Pentosans in	Alpha-basis: original ash- and pentosan-free
		%	%	%	%	%	%	%	%	%	%	%	%
9851	Hawaiian whole bagasse - variety 1933 (Oahu Sugar Co.)	7.9	3.3	20.1	31.0	2.7	3.4	32.0	52.0	32.4	65.7	7.4	31.7
10081	Puerto Rican whole bagasse (Aguirre 1951, 1952)	7.5	3.9	18.1	29.6	8.0	5.4	27.3	50.9	31.1	63.7	7.0	30.1
10081	Puerto Rican bagasse fiber (Aguirre 1951, 1952)	11.5	1.2	19.8	31.6	1.4	2.7	27.3	59.9	30.4	67.2	5.7	40.2
10081	Puerto Rican bagasse pith (Aguirre 1951, 1952)	4.9	3.2	18.8	31.9	2.8	2.9	30.3	53.9	30.3	60.4	6.4	32.6
10564	Mexican bagasse pith (San Cristobal, 1953)	6.2	4.9	22.4	29.9	7.6	2.3	40.1	46.0	25.5	61.3	5.5	26.6
10566	Philippine whole bagasse (Negros Island, 1952)	10.2	2.3	22.3	31.8	2.8	3.0	31.3	56.8	30.6	70.2	12.5	34.9
10566	Philippine bagasse fiber (Negros Island, 1952)	5.3	1.2	21.8	31.2	1.9	2.1	26.8	62.9	31.9	72.0	9.1	41.2
10566	Philippine bagasse pith (Negros Island, 1952)	3.3	2.6	22.5	33.2	3.6	2.7	36.2	55.4	32.2	66.8	5.7	34.9

Table 2.-Proximate physical analyses of various samples of whole bagasse results reported on original bagasse o.d. basis

Type of whole bagasse	Florida variety F. 31-962 (1952)	Florida variety Cl. 41-223 (1952)	Louisiana Thibodaux stored (1952)	Hawaiian variety 8560 (1952)	Puerto Rico Aguirre (1951-52)	Philippine Islands Negros (1952)
	%	%	%	%	%	%
Fiber	58.0	60.7	64.4	60.5	60.1	68.6
Pith	22.8	24.3	25.2	32.9	25.5	23.8
Solubles, dirt and loss	19.2	15.0	10.4	6.6	14.4	7.6

Table 3.-Variations in true fiber and pith content of certain varieties of Florida sugarcane. Percent based on dry bagasse free from dirt and solubles

Cane variety	Fiber	Pith	$\frac{\text{Fiber}}{\text{Pith}}$ Ratio
	%	%	
F. 31-436	69.6	30.4	2.289
P.O.J. 2725	65.4	34.6	1.890
Cl. 38-32	78.1	21.9	3.566

Table 4.-Separation-yield data. Hawaiian bagasse samples

Run no.	Bagasse o.d.	Consistency	Pulping time	Fiber	Pith	Tailings	Pith and tailings	Fiber, pith and tailings	Pulp-effluent loss	Dewatering-screen loss[1]		Undetermined loss
										1st pass	2nd pass	
	Lb.	%	Min.	%	%	%	%	%	%	%	%	%
Bagasse Lot No. 9333. Laupahoehoe Sugar Company. Air-dried, nonshredded.												
45	51.8	7.1	30	55.1	20.2	7.4	27.6	82.7	2.5		5.3	9.5
47	50.0	7.1	23	56.9	21.3	8.9	30.2	87.1	2.4		5.4	5.1
48	50.0	7.1	37	53.6	21.9	10.2	32.1	85.7	2.9		5.7	5.6
Bagasse Lot No. 9334. Laupahoehoe Sugar Company. Damp, nonshredded.												
56	50.9	7.1	30	56.1	17.4	9.7	27.1	83.2	4.2	7.3	3.1	2.2
57	50.9	7.1	23	57.2	18.5	8.0	26.5	84.7	4.0	6.8	3.3	2.2
58	50.9	7.1	30	55.3	19.7	7.6	27.3	82.6	4.1	7.5	3.4	2.4
Bagasse Lot No. 9562. Oahu Sugar Company. Variety 1933, 1st ratoon, air-dried, shredded.												
53	49.7	7.0	30	50.8	20.2	9.4	29.6	80.4	4.5	8.5	3.0	3.6
54	49.7	7.1	23	53.0	20.2	10.0	30.2	83.2	4.7	6.6	4.7	0.8
55	49.7	7.1	30	48.2	25.3	9.4	34.7	82.9	4.3	9.3	2.9	.6

[1] Fines passing through dewatering screen collected in filter bags for runs 45, 47, and 48; total solids determined on aliquot part of all water passing through dewatering screen for runs 53 to 56.

Table 5.-Hydrapulper treatment to loosen pith from fiber in various lots of bagasse

NRRL no.	Type of whole bagasse: Location	Mill	Date crop year	Variety	Size fibers	Fiber	Hydrapulper treatment[1]: Temperature	Maximum consistency	Time required	Approximate power
						%	°F.	%	Min.	Kw.hr.
9334	Hawaii	Laupahoehoe	1950		Fine damp	61	100-117	7.1	23	14.5
9562	"	Oahu	1951	1933	Fine	58	100-117	7.1	23	14.5
9573	"	Ewa	1951	1933	Coarse	62	102-118	6.8	30	12.0
9574	"	Oahu	1951	8560	Fine	56	100-115	7.1	15	16.0
9903	"	"	1951	Mixed	Damp fine	55	100-109	7.9	12	17.0
9382	Florida	U.S. Sugar	1950	Mixed	Dried coarse	59	100-130	6.4	33	18.0
9940	"	" "	1952	Cl. 41-223	Dried fine	63	100-113	6.5	15	-
9942	"	" "	1952	F. 31-962	Dried fine	65	99-111	6.4	15	-
9941	"	" "	1952	F. 31-436	Dried fine	61	93-110	5.7	15	-
10366	"	" "	1953	F. 31-436	Coarse	63	100-135	6.5	24	19.0
10002	Louisiana	Iberia Sugar	1952	Mixed	Fine dried	53	100-118	7.5	15	-
10081	Puerto Rico	Aguirre	1952	Mixed	Fairly fine	57	100-118	6.2	18	-
10566	Philippine	Negros Island	1953	Mixed	Fairly fine		102-120	6.5	16	17.6

[1] Fifty-pound charges were used.

Table 6.-Hydrapulper extraction-plate method used for separating 12,000 lb. Florida variety F. 31-436 (1952-53) bagasse into pith and fiber

	O.d. basis
	%
Coarse fiber from pulper	49.3
Fine fiber Jonsson screen	13.4
Total fiber	62.7
Pith	27.3
Dirt, solubles, and loss (estimated)	10.0
	100.0

Table 7.-Summary of test data - Bauer disc mills for loosening pith from fiber of bagasse (25% consistency)

Refiner	Plates	No. of runs	Range of settings	Capacity o.d. tons /day	Brake hp. days/ton	Comments
Double-disc No. 400	1/2" devil-tooth B-980 B-981	13	0.500-0.600	27-65	1.3-2.6	Depithing satisfactory. Capacity limited by feed opening. Large volume of water required.
Single-disc No. 245	1" devil-tooth B-940 B-941	3	0.400-0.500	65-75	0.8-1.6	Depithing unsatisfactory.
" " " "	1/2" devil-tooth B-940 B-941	5	Contact-0.500	-	-	Depithing unsatisfactory. Cut fibers at contact.
" " " "	Wash board B-915 B-916	6	0.100-0.500	-	-	Depithing unsatisfactory. Fibers cut.
" " " "	Waveline B-968 B-969	17	Contact-0.075	57-120	0.8-3.2[1]	Depithing satisfactory. Capacity adequate.

[1] High power reading occurred when refiner was overloaded at close setting.

Table 8.-Jonsson screen study. Screening capacity

Screen perforation diameter, in.	0.08	0.09	0.12	0.12
Run no.	106	115	114	116
Calculated feed consistency, %	0.68	0.58	0.57	0.65
Total feed rate, lb./min.	652	611	637	570
Fiber discharge rate, lb./min.	2.94	2.15	2.30	2.34
Pith discharge rate, lb./min.	1.48	1.38	1.35	1.34
Total solids discharge rate, lb./min.	4.42	3.53	3.65	3.68
Fiber, % total discharge	66	61	63	64
Capacity as screen area, sq. ft./lb./min.	1.53	1.92	1.86	1.84
Fiber quality, visual estimate	Fair	Good	Good	Good
Pith quality, visual estimate	Fair	Fair	Poor	Poor
Consistency of pith discharge, %	0.22	0.23	0.23	0.26
% Tailings removed by rescreening	-	15.2	24.3	23.7
Rescreening rate, sq. ft./lb./min.	-	3.65	3.37	3.15
Bauer-McNett analysis				
First pass o.d. pith				
% Retained - 8 mesh	10.8	13.2[1]	-	20.4[1]
14 mesh	28.7	25.4	-	24.4
100 mesh	59.8	60.4	-	54.2
200 mesh	0.7	1.0	-	1.0

[1] Original Bauer-McNett analysis for these runs was made on pith screens was high, 7 to 8%. Distribution was recalculated on with other runs.

[2] Pith from runs 121a and 121b was combined before Bauer-McNett

and quality of products vs. consistency and screen size

0.12 :	0.25	0.25	0.25	0.25	0.25 :	0.44	0.44	0.44	0.44
107	122	121b	105	121a	104	128a	128b	130	129
0.96	0.69	0.88	0.94	1.10	1.11	0.90	1.12	1.21	1.53
459	683	566	563	778	458	854	662	777	680
2.63	3.07	3.32	3.30	5.74	3.07	4.73	4.01	5.15	6.78
1.77	1.63	1.65	1.98	2.77	2.02	2.95	3.38	4.24	3.65
4.40	4.70	4.97	5.28	8.51	5.09	7.68	7.39	9.39	10.43
60	65	67	62	67	60	61	54	55	65
1.54	1.44	1.36	1.28	0.80	1.33	0.88	0.92	0.72	0.65
Good Poor	Good Poor	Fair Poor	Good Poor	Poor Poor	Poor Poor	Good Very poor	Good Very poor	Fair Very poor	Fair Very poor
0.40	0.25	0.34	0.33	0.32	0.42	0.34	0.47	0.55	0.51
-	25.1	23.4	-	-	-	50.0	54.5	56.5	57.8
-	2.04	1.40	-	-	-	-	-	1.81	-
21.5	22.0	21.5[2]	22.8	21.5[2]	17.7	39.2	36.8	32.5	32.9
29.5	27.6	27.3	26.6	27.3	23.3	23.6	23.7	22.8	22.6
48.2	49.9	49.3	49.7	49.3	57.9	36.7	38.8	44.2	44.0
0.8	0.5	1.9	0.9	1.9	1.1	0.5	0.7	0.5	0.5

collected on vacuum filter. As such, % retained on the 200-mesh basis of 1.0% retained on 200-mesh screen for better comparison

analysis was made.

Table 9.--Flat screen study

Perforation diameter, in.	0.09	0.19	0.19	0.19
Run no.	118a	119a	119b	120a
Feed consistency, %	0.77	0.74	0.78	0.57
Total feed rate, lb./min.	640	710	395	546
Fiber discharge rate, lb./min.	2.98	3.61	1.90	2.16
Pith discharge rate, lb./min.	1.96	1.64	1.18	0.91
Total solids discharge rate, lb./min.	4.94	5.25	3.08	3.09
Screen area, sq. ft./lb./min.	1.93	1.81	3.08	3.05
Fiber quality, visual estimate	Fair	Fair	Fair	Fair
Bauer-McNett analysis				
First pass o.d. pith				
% Retained - 8 mesh	16.2	19.3	17.7	21.5
14 mesh	28.3	28.6	28.1	27.8
100 mesh	54.8	51.2	53.3	49.8
200 mesh	0.7	0.9	0.9	0.9

Table 10.-Data from run H 8 on use of Centri-Cleaner 12" x 3" x 3" with 1 3/4" tip size. To separate bagasse into fiber and pith

	First pass	Assumed second pass rejects
Material in		
Wt. pulp lb. o.d.	8.03	3.6
Consistency, %	0.258	0.25
Gallons	373	168
Pumping rate, g.p.m.	520	520
Inlet pressure, p.s.i.	70	70
Rejected material		
Wt. lb. o.d.	3.6	1.62
% by weight o.d.	45	45
Consistency, %	1.25	1.25
Gallons	35	13
Accepted material		
Wt. lb. o.d.	4.4	1.98
% by weight o.d.	55	55
Consistency, %	0.155	0.155
Gallons	338	155

Table 11.-Analysis of accepted and rejected material obtained in test run H 8 with Centri-Cleaner

	Accepted : % of material fed	Rejected : % of material fed	Total
First pass	55.0	45.0	100.0
Fiber	33.2	33.2	66.4
Pith	21.8	11.8	33.6
Assumed second pass	24.3	20.7	45.0
Fiber	16.6	16.6	33.2
Pith	7.7	4.1	11.8
Total two passes	79.3	20.7	
Fiber	50.0	16.4	66.4
Pith	29.5	4.1	33.6

- - -

Table 12.-Screen dimensions. Link-Belt dewatering unit

Mesh	Opening	Open area
	In.	%
100	0.0055 x 0.0055	30.2
120	0.0046 x 0.0046	30.7
75 (Fourdrinier)	0.0061 x 0.0109	27.2

Table 13.-Capacity and loss analysis.
Link-Belt dewatering screen

Run number	Feed consistency	Maximum feed rate	Pith yield: Insoluble solids to screen	Pith recovered	Screen capacity	Dewatering loss: o.d. whole bagasse	Decanting loss: o.D. whole bagasse	Slope of screen	Solids content pith discharge
	%	Lb./min.	%	Lb./min.	Sq.ft./lb. pith/min.	%	%	Degrees	%
100-Mesh wire screen - 6.71 sq. ft. effective area									
63	0.28	258	62.2	0.44	15.3	9.09	-	-	5.9
64	.26	416	59.6	.63	10.7	10.33	-	0	5.7
65	.17	616	60.5	.62	10.8	10.87	-	0	5.2
66	.17	600	50.9	.51	13.2	11.83	-	0	-
67	.43	291	67.1	.83	8.1	7.69	2.10	-1 1/2	-
68	.46	250	68.2	.77	8.7	6.94	1.54	0	-
71 and 72	.96	250	74.7	1.77	3.8	7.24	Not collected	-1 1/2	6.1
120-Mesh wire screen - 6.94 sq. ft. effective area									
73 and 74 (1st pass)	.83	395	73.8	2.30	2.9	8.80[1]	Not collected	-2 1/2	-
75 and 76	1.04	300	78.5	2.42	2.9	6.97	" "	-1 1/2	6.5
75-Mesh Fourdrinier wire - 6.94 sq. ft. effective area									
77 and 78	1.09	321	73.0	2.52	2.8	8.75	Not collected	-1 1/2	6.5
79	0.60	616	68.5	2.49	2.8	10.38	" "	-1 1/2	6.1
80, 81, and 83	1.35	284	74.7	2.83	2.5	7.81	" "	-1 1/2	6.3
88	0.27	1,034	58.8	1.61	4.3	13.70	" "	-2 1/2	5.4

[1] Increased from recorded value of 6.48% to include all of pith from both runs.

Table 14.-Pith filtration. Bird Machine - 150, total area

Run no.	Bagasse no.	Pith slurry consistency	Filtrate rate Gal./sq.ft./min. 9 sec.	18 sec.	27 sec.	Filter cake rate Lb./sq.ft./min. 9 sec.	18 sec.	27 sec.
		%						
								Hawaiian
102A	9574	0.37	30.0	20.7	15.4	0.67	0.42	0.28
102B	9574	1.37	17.2	12.0	10.5	1.42	.88	.75
102C	9574	1.03	18.5	13.0	12.3	1.00	.65	.59
102D	9574	0.68	20.5	14.7	12.9	0.70	.53	.45
102E	9574	.24	32.7	22.3	19.3	.46	.28	.23
102F	9574	.19	40.5	29.5	23.5	.38	.37	.22
103	9851	.28	29.3	20.7	17.0	.45	.30	.23
104	9851	.42	24.3	17.0	13.2	.53	.35	.23
105	9851	.33	26.7	18.3	15.4	.49	.34	.27
106	9851	.22	29.4	21.0	16.7	.44	.27	.21
107	9851	.40	27.0	17.6	14.9	.68	.35	.29
								Florida
108	9941	.22	23.7	17.3	13.3	.28	.20	.13
110	9942	.21	26.2	15.3	12.6	.26	.12	.10
112	9940	.23	23.5	16.2	12.5	.30	.19	.13

Bagasse No. 9574 - Variety 8560 Oahu Sugar Company, Hawaii
9851 - " 1933 " " " "
9941 - " F. 31-436 U. S. Sugar Corporation, Florida
9942 - " F. 31-962 " " " "
9940 - " Cl. 41-223 " " " "

Company filter test apparatus. Wire mesh - 0.01 sq. ft.

Solids lost in filtrate, %			Cake thickness, inches x 16			Filter cake moisture, %		
9 sec.	18 sec.	27 sec.	9 sec.	18 sec.	27 sec.	9 sec.	18 sec.	27 sec.
bagasse								
16.5	--	--	5	6	6	85.6	86.4	85.9
6.2	--	--	10	11	11	87.3	86.8	86.9
7.5	--	--	7	10	10	87.2	86.5	86.0
10.7	--	--	6	8	8	87.4	85.9	85.4
15.7	--	--	4	5	6	88.0	86.7	87.1
15.7	--	--	3	6	5	88.0	85.6	85.4
11.1	13.5	11.4	4	5	5	88.7	87.7	86.7
11.3	10.4	14.5	5	6	5	87.7	87.0	86.0
12.8	10.6	11.3	5	7	6	87.8	87.5	86.2
12.0	11.2	11.4	4	5	6	89.0	87.5	86.6
8.9	13.3	13.8	6	6	7	88.4	86.9	86.0
bagasse								
11.0	11.2	12.6	3	5	4	91.6	90.9	89.5
11.9	12.8	12.6	3	3	3	91.8	90.7	89.8
9.9	10.6	16.2	4	4	4	92.0	90.5	90.9

Table 15.-Zenith press tests

Run no.	1	2	3
Feed material			
Dry pith, lb.	14	26	14
Total weight, lb.	233	130	900
Estimated consistency, %	6.0	20.0	1.5
Consistency by analysis, %	6.79	16.1	1.59
Time of run, min.	2.0	5.6	3.7
Air pressure on cone, p.s.i.	15	10	20
Spindle speed, r.p.m.	6	6	6
Motor, amp.	8-10	7.5	8
Outside effluent, lb.	126	72	683
Spindle effluent, lb.	56	15	169
Pith discharge, lb.	24	60	27
Solids in pith discharge, %	40.4	39.0	34.3
Outside effluent loss, %	2.8	0.5	11.0
Spindle effluent loss, %	0.8	0.1	1.8
Pith recovery, %	96.4	99.4	87.2
Pith discharge rate, lb./hr.	291	252	152
Total throughput rate, lb./hr.	6,180	1,580	14,400

Table 16.--Screening tests by Orville Simpson Company using commercial No. 11 rotex screen to separate processed dry Puerto Rican bagasse into fiber and pith

Run no.	Top screen			Bottom screen			Total material retained fiber	Total material passed pith	Feed rate	Fiber present in pith fraction
	Mesh	Opening	Material retained	Mesh	Opening	Material retained				
		In.	%		In.	%	%	%	Lb./sq. ft./hr.	%
1	10	0.0800	72.9	16	0.0465	12.14	85.04	14.96	122.3	5.0
2	8	.1000	57.0	12	.0650	13.65	70.65	29.35	105.5	9.4
3	6	.1390	44.5	10	.0800	19.15	63.65	36.35	80.6	13.0

Table 17.-Screening tests of various dry samples of pith-loosened bagasse using NURB Rotex No. 11 screen dressed with special perforated plate screens

Run no.	Fiber retained on 1st screen 0.436" diameter	Fiber retained on 2nd screen 0.156" diameter	Fiber retained on 3rd screen 0.095" diameter	Total fiber retained on the three screens	Crude pith passing .095" screen	Fiber present in crude pith	Theoretical yield of pith-free fiber	Theoretical yield of fiber-free pith
	%	%	%	%	%	%	%	%
Florida bagasse No. 10366, Variety F. 31-436, from U. S. Sugar Corporation. Pith partially removed at mill.								
495	39.2	33.5	12.1	84.8	15.2	16.0	83.0	17.0
Hawaiian bagasse No. 10098, Variety 8560, from Oahu Sugar Company.								
496	19.6	30.9	13.6	64.1	35.9	11.0	64.8	35.2
Philippine bagasse No. 10566, from Negros Island, sent by Oscar Kohorn and Company.								
497	29.8	29.6	14.4	73.8	26.2	15.5	74.2	25.8
Louisiana bagasse (stored) No. 10444, from Celotex Corporation, Thibodaux, Louisiana.								
498	17.6	34.4	19.4	71.4	28.6	14.5	72.0	28.0
Puerto Rican bagasse No. 10081, from Central Aguirre Sugar Company.								
499	22.4	30.2	17.4	70.0	30.0	12.4	70.2	29.8
Florida bagasse No. 9940, Variety Cl. 41-223, from U. S. Sugar Corporation.								
500	18.4	32.2	18.7	69.3	30.7	17.6	72.6	27.4
Florida bagasse No. 9942, Variety F. 31-962, from U. S. Sugar Corporation.								
501	28.3	28.1	15.7	72.1	27.9	11.4	72.7	27.3

Note.- Feed rate was 80.6 lb./sq. ft./hr.
Separated fiber contained 5 percent of pith.

Table 18.-Screening tests of various samples of pith-loosened bagasse, moisture content 60%, using NURB Rotex No. 11 screen dressed with special perforated plate screens

Run no.	Fiber retained on			Total fiber fraction	Total pith fraction	Feed rate
	1st screen 0.436" diameter	2nd screen 0.156" diameter	3rd screen 0.095" diameter			
	%	%	%	%	%	Lb./sq.ft./hr.
J	Florida bagasse No. 10366, Variety F. 31-436, pith partially removed, from U. S. Sugar Corporation.					
	52.2	21.6	11.7	85.5	14.5	37.4
3A	Hawaiian bagasse No. 10098, Variety 8560, from Oahu Sugar Company.					
	16.9	31.0	16.6	64.5	35.5	35.3
4A	Puerto Rican bagasse No. 10081, from Central Aquirre Sugar Company.					
	39.9	23.1	10.4	73.4	26.6	41.5

Table 19.-Operating data for the drying of pith, pith-free fiber, and whole bagasse

	Drying pith		Drying fiber	Drying whole bagasse
Type of drier	Flash	Rotary H	Rotary parallel flow	Heil rotary
Tons of o.d. product dried/day	30	30	67	48
Size	10' diameter cyclone	6' x 40'	7' x 45'	8' x 25'
Lb. of water evaporated/hr.	3,470	3,470	4,495	6,000
Original moisture, %	60	60	45	50
Final moisture, %	10-12	10-12	10	10-12
Inlet temperature, °F.	1,250	1,300	800	-
Outlet temperature, °F.	350	245	230	-
Temperature of product, °F.	150	140	100	-
Air velocity	-	350-430'/min.	250'/min.	-
Speed of cage mill	1,200 r.p.m.	-	-	-
Total power required/hr., kw.hr.	52	30	30	34
Gal. of oil used/hr.	56	45	57	90
Quality of product	Good, no lumps	Good, no lumps	Good, no burning	-

Table 20.-Analysis of juice obtained by treating fresh bagasse with an equal weight of water and pressing under 2,000 p.s.i. pressure

Sample	Bagasse (50% moisture)	Water added[1]	Liquor extracted	Brix	Sucrose content	Purity juice	Yield of sucrose/ton bagasse
	Gram	Gram	Ml.	Degree	%	%	Lb.
1	100	150	ca. 140	2.72	1.91	70.2	53.6
2B	100	150	152	2.76	1.94	70.3	59.0
			Average				56.3
2	100	100	102	3.16	2.39	75.6	48.8
3	100	100	100	3.37	2.47	73.3	49.4
4	100	100	100	2.93	2.26	77.1	45.2
			Average				47.8
			Total average				51.2

[1] Water was spread on bagasse immediately before pressing.

Table 21.-Estimated capital costs of
Basis: 100 tons

	Case 1 A				
	Size of equipment	No. required	Total connected hp.	Installed cost	Size of equipment
Mill, single-disc	36" diameter	1	100	$12,000	36" diameter
Roll, sugar-mill	3 roll	1	75	30,000	3 roll
Drier, rotary, parallel (fiber pith)	7' x 45'	2	80	50,000	-
Drier, rotary, parallel (for fiber)	-	-	-	-	7' x 45'
Drier, rotary, type H (for pith)	-	-	-	-	-
Screen, Rotex (3 deck)	5' x 10'	4	12	19,100	5' x 10'
Total			267	$111,100	

pith-separation processes at sugar mill, o.d. bagasse/day

Case 2 A				Case 3 A		
No. required	Total connected hp.	Installed cost	Size of equipment	No. required	Total connected hp.	Installed cost
1	100	$12,000	36" diameter	1	100	$12,000
1	75	30,000	3 roll	1	75	30,000
-	-	-	-	-	-	-
1	40	25,000	-	-	-	-
-	-	-	6' x 40'	1	40	28,000
8	24	38,000	5' x 10'	8	24	38,000
	239	$105,000			239	$108,000

Table 22.-Estimated operating expense to separate whole bagasse at sugar mill into pith-free fiber and pith.
Case 1 A - whole bagasse dried before screening, fiber baled; pith mixed with molasses and pelleted.
Basis: 100 ton o.d. bagasse/day

	Per ton o.d. bagasse		
	100-day operation	180-day operation	300-day operation
Fuel and power	$1.781	$1.781	$1.781
Labor, supervision, maintenance, and supplies	1.383	1.156	1.042
Fixed charges	1.436	0.992	0.769
Total	4.60	3.929	3.592
Credit for sugars recovered	1.00	1.00	1.00
Net operating expense/o.d. ton	3.60	2.929	2.592
Cost/o.d. ton fiber or pith, 90% yield	4.00	3.25	2.88
Fuel value/o.d. ton pith and fiber	2.50	2.50	2.50
Cost/o.d. ton baling fiber or pelleting pith	2.50	2.50	2.50
Cost/o.d. ton baled fiber or pelleted pith	$9.00	$8.25	$7.88

Table 23.-Estimated operating expense to separate whole bagasse at sugar mill into pith-free fiber and pith.
Case 2 A - fiber dried and baled after wet screening; pith burned wet as fuel
Basis: 100 ton o.d. bagasse/day

	Per ton o.d. bagasse		
	100-day operation	180-day operation	300-day operation
Fuel and power	$0.896	$0.896	$0.896
Labor, supervision, maintenance, and supplies	1.355	1.14	1.033
Fixed charges	1.381	0.961	0.751
Total operating expense/o.d. ton	3.632	2.997	2.68
Credit for sugars recovered/o.d. ton bagasse	1.00	1.00	1.00
Net operating expense/o.d. ton	2.632	1.997	1.68
Cost/o.d. ton fiber and pith, 90% yield	2.92	2.22	1.87
Cost/o.d. ton fiber on basis of 68.4% yield with pith of no value	3.85	2.92	2.46
Fuel value/o.d. ton fiber	2.50	2.50	2.50
Cost baling/o.d. ton fiber	2.50	2.50	2.50
Cost/o.d. ton baled fiber	$8.85	$7.92	$7.46

Table 24.- Estimated operating expense to separate whole bagasse at sugar mill into pith-free fiber and pith
Case 3 A - bagasse pith dried, mixed with molasses and pelleted after screening; fiber burned wet as fuel.
Basis: 100 tons o.d. bagasse/day

	Per ton o.d. bagasse		
	100-day operation	180-day operation	300-day operation
Fuel and power	$0.67	$0.67	$0.67
Labor, supervision, maintenance, and supplies	1.369	1.149	1.038
Fixed charges	1.408	0.976	0.76
Total operating expense/o.d. ton	3.447	2.795	2.468
Credit for sugars recovered/o.d. ton bagasse	1.00	1.00	1.00
Net operating expense/o.d. ton	2.447	1.795	1.468
Cost/o.d. ton fiber and pith, 90% yield	2.72	1.99	1.63
Cost/o.d. ton pith on basis of 21.6% yield with fiber of no value	11.33	8.31	6.79
Fuel value/o.d. ton pith	2.50	2.50	2.50
Cost of mixing pith with molasses and pelleting/ton	2.50	2.50	2.50
Total cost/o.d. ton of pelleted mixture	$16.33	$13.31	$11.79

Table 25.--Estimated capital costs of pith-
Basis: 100 ton

	Case 1 B				
	Size of equipment	No. required	Total connected hp.	Installed cost	Size of equipment
Hydrapulper	11'	2	300	$37,250	11'
Mill, single-disc	-	-	-	-	-
Screen, Jonsson	21.7 sq.ft.	10	30	50,000	21.7 sq.ft.
Screen, Rotex, 3-deck	-	-	-	-	-
Roll, sugar-mill	-	-	-	-	-
Filter, rotary vacuum	125 sq.ft.	1	150	28,000	125 sq.ft.
Press, dewatering	Zenith ZL	1	20	18,000	Zenith ZL
Regulator, consistency		1	-	1,500	-
Tank, storage - with agitator	10,000 gal.	2	20	20,000	10,000 gal.
Tank, settling	20,000 gal.	1	-	2,000	20,000 gal.
Pump, trash, 1,000 g.p.m.	15"	2	50	4,000	-
Pump, water, 3,800 g.p.m.	-	-	-	-	10"
Pump, water, 75 g.p.m.	2"	1	1.5	400	2"
Total			572	$161,150	

separation processes using stored bagasse.
o.d. bagasse/day

Case 2 B				Case 3 B		
No. required	Total connected hp.	Installed cost	Size of equipment	No. required	Total connected hp.	Installed cost
2	300	$37,250	11'	1	150	$18,625
-	-	-	36"	1	150	13,000
2	6	10,000	-	-	-	-
-	-	-	5' x 10'	8	24	38,000
-	-	-	3 roll	1	75	30,000
1	150	28,000	-	-	-	-
1	20	18,000	-	-	-	-
-	-	-	-	-	-	-
1	10	10,000	-	-	-	-
1	-	2,000	20,000 gal.	1	-	2,000
-	-	-	-	-	-	-
1	40	2,500	10"	1	40	2,500
1	1.5	400	2"	1	1.5	400
	528	$108,150			441	$104,525

Table 26.-Estimated operating expense to separate whole stored bagasse into pith-free fiber and pith.
Basis: 100 ton o.d. bagasse/day

	Per ton o.d. bagasse		
	Case 1 B: 300-day operation	Case 2 B: 300-day operation	Case 3 B: 300-day operation
Cost baled bagasse/o.d. ton	$9.90	$9.90	$9.90
Water and power	0.859	0.675	0.721
Labor, supervision, maintenance, and supplies	1.118	1.038	1.032
Fixed charges	0.919	0.76	0.75
Total operating expense/o.d. ton	12.796	12.373	12.403
Cost/o.d. ton fiber and pith, 90% yield	14.22	13.75	13.78
Cost/o.d. ton fiber on basis of 68.4% yield with pith of no value	18.71	18.09	18.13

Table 27.-Comparison of costs of pulps in terms of raw fiber, based on cost of whole bagasse $9.90/o.d. ton and pith-free fiber
Case 1 A, $9.00; 2 A, $8.85; and 3 B, $13.78/o.d. ton

Neither the profit on the separation operation nor the cost of pulping chemicals is included. It is assumed that the recovered pith has the same commercial value as the fiber.

	Pith-free fiber				Whole bagasse	
	cost o.d. ton pulp				cost o.d. ton pulp	
	Yield	1 A	2 A	3 B	Yield	
Bleached 80 brightness	48	$18.74	$18.44	$28.70	37	$26.75
Unbleached	60	15.00	14.75	22.95	48	20.62
Corrugating	75	12.00	11.80	18.37	65	15.23

Table 28.-Data on absorption capacity of bagasse pith and feed absorbents used in livestock feeds

	Absorption		
	Apparent density	Average absorption, g.water/3-g. sample	Time for absorption
	Lb./cu. ft.		Sec.
Wet-separated bagasse pith prepared by NURB			
Scheme 1			
Hawaiian bagasse	2.6	26.0	40
Hawaiian bagasse specially screened	2.0	29.5	50
Puerto Rican bagasse	2.2	25.8	58
Florida bagasse	2.5	24.3	42
Scheme 2			
Hawaiian bagasse	3.0	24.5	42
Puerto Rican bagasse	3.3	26.2	50
Florida bagasse	3.5	23.1	39
Scheme 3			
Hawaiian bagasse	3.4	24.9	68
Puerto Rican bagasse	3.3	26.2	100
Florida bagasse	3.7	25.5	59

--Continued

Table 28.-Data on absorption capacity of bagasse pith and feed absorbents used in livestock feeds--Continued

	Absorption		
	Apparent density	Average absorption, g.water/3-g. sample	Time for absorption
	Lb./cu. ft.		Sec.
Dry-screened pith from various sugar companies			
Company A dehydrated fines	4.8	15.3	60
Company A screen dust	5.4	13.6	110
Company A dust from dust collector	4.2	14.6	111
Company B 40-mesh dust	4.5	13.7	--
Company B screened pith	5.7	20.3	--
Alfalfa meal, 17% dehydrated	18.5	7.7	400
Barley chaff	15.0	8.9	210
Barley dust	13.1	10.6	250
Beet pulp	14.6	14.4	270
Cottonseed meal	33.0	6.5	500
Gluten feed	25.7	6.8	27
Linseed meal, extracted	30.4	8.2	--
Malt sprouts	15.9	14.9	3,200
Oat feed, No. 9 or B grade	18.7	7.9	25
Pin oats, hulls, and dust	8.0	11.7	160
Oats, pulverized	24.8	5.5	1,860
Screenings, ground grain	19.1	6.7	63
Screenings, lightweight No. a	16.8	8.2	25
Screenings, lightweight No. b	17.5	7.7	45
Screenings, soybean	22.7	12.0	260
Soybean meal, extracted	40.3	6.0	40
Wheat bran	11.4	11.4	82
Wheat and elevator dust	10.0	13.6	75
Wheat hulls and dust	14.4	11.1	65

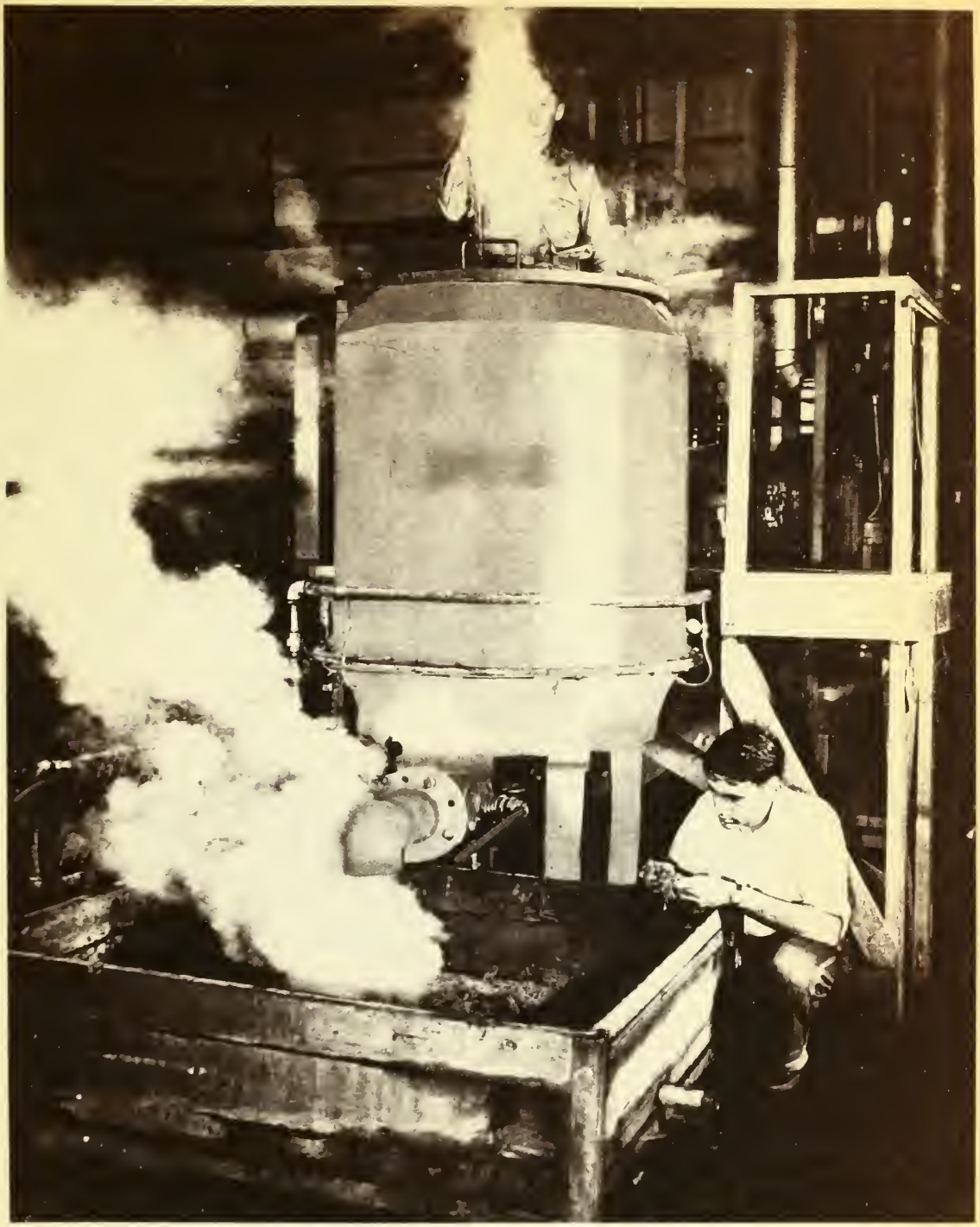


Figure 1. 3-foot Hydrapulper

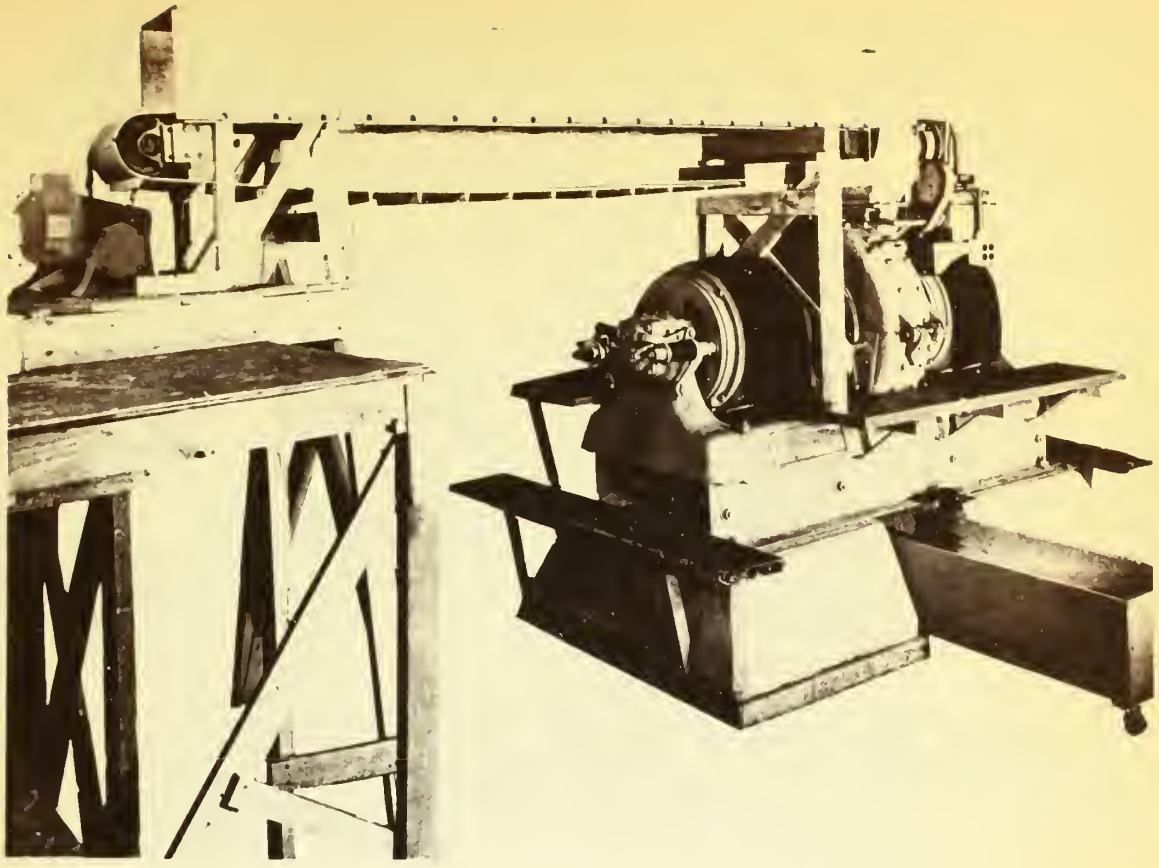
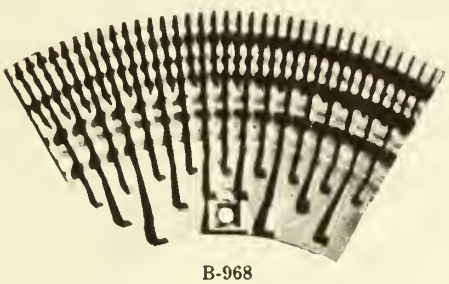
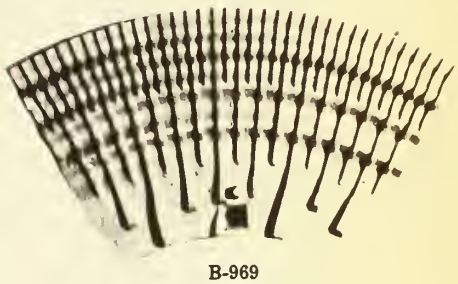


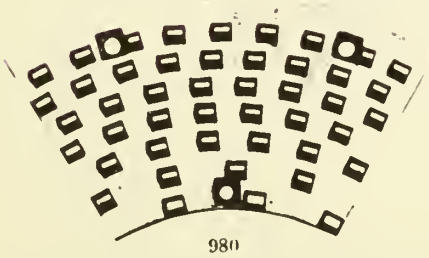
Figure 2. 24-inch double-disc mill



B-968



B-969



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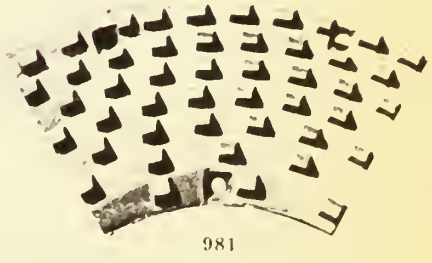


981

Figure 3. Patterns of wave-line and devil-tooth plates

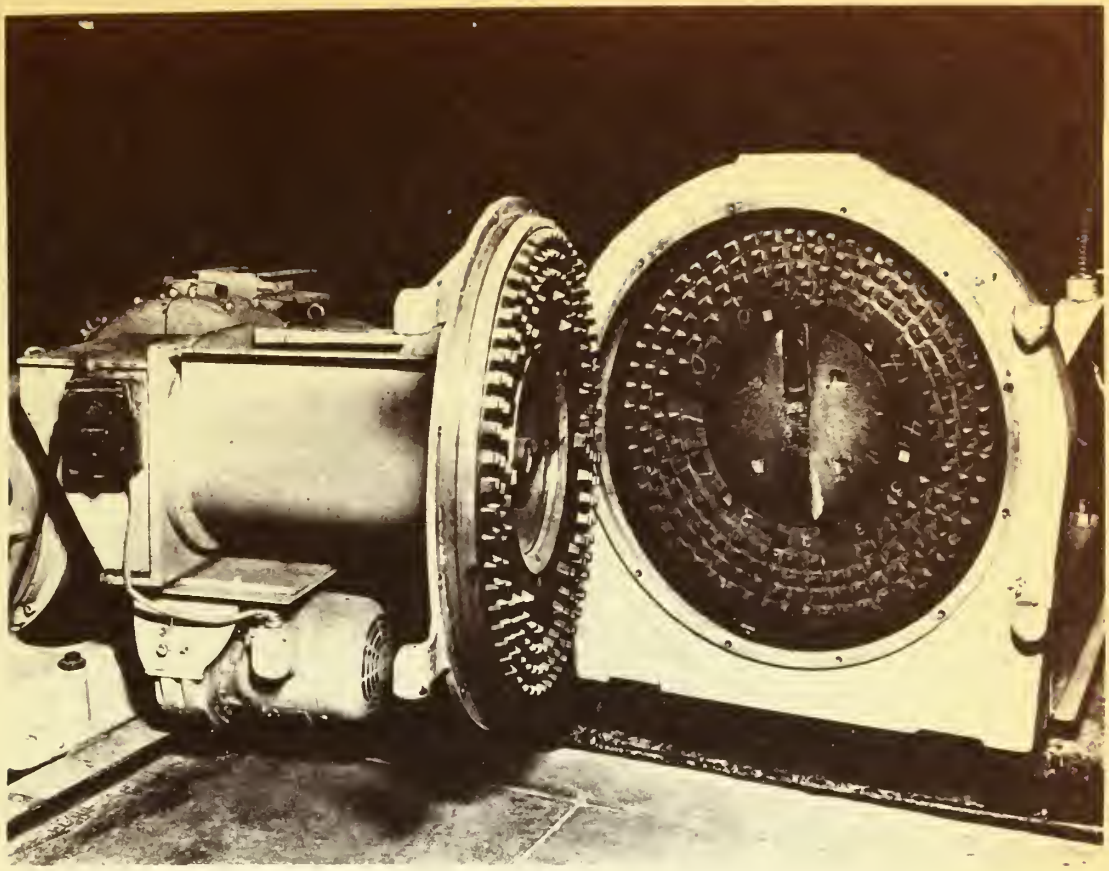


Figure 4. 36-inch single-disc mill

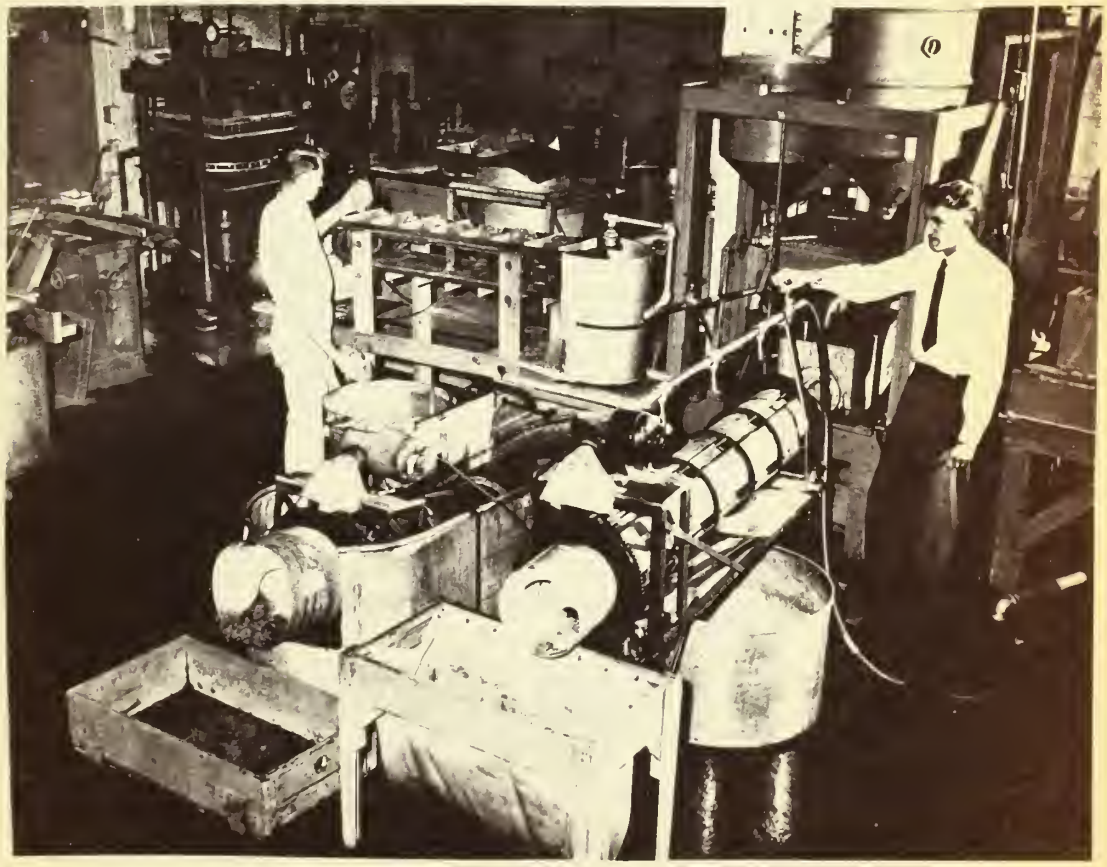


Figure 5. Rotary screen (left) and pith dewatering screen (right) in operation

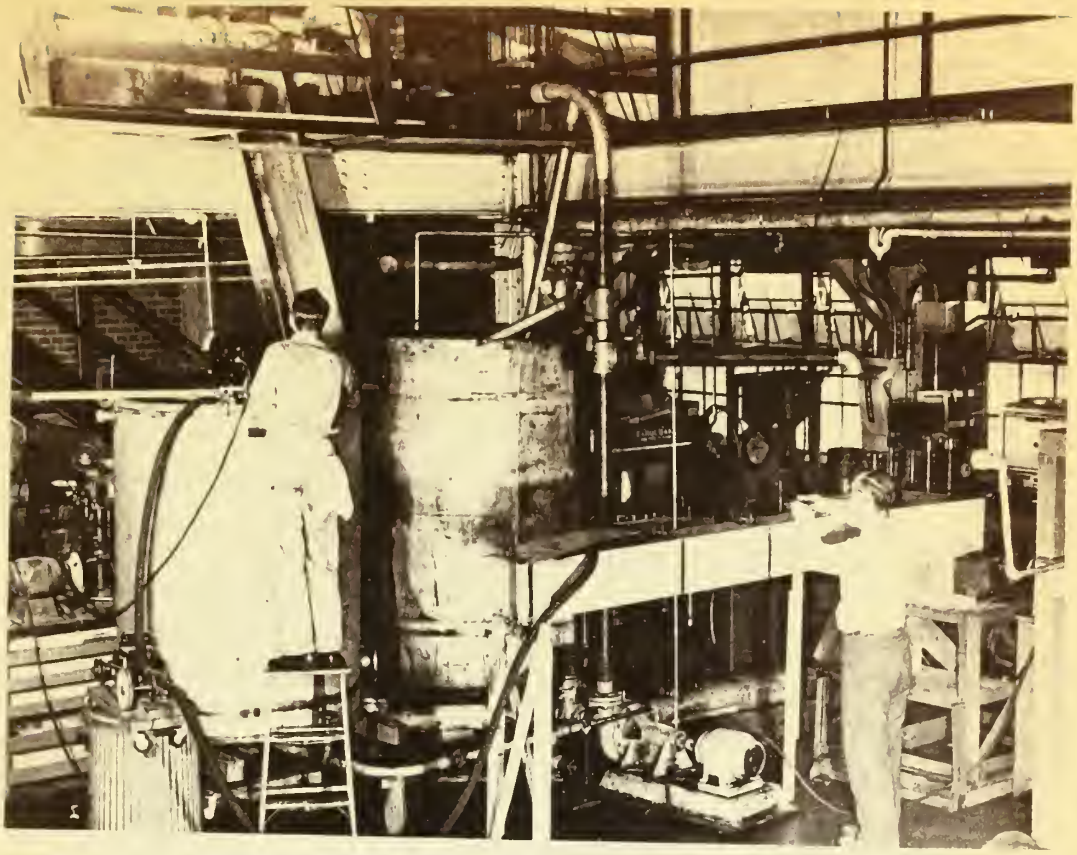
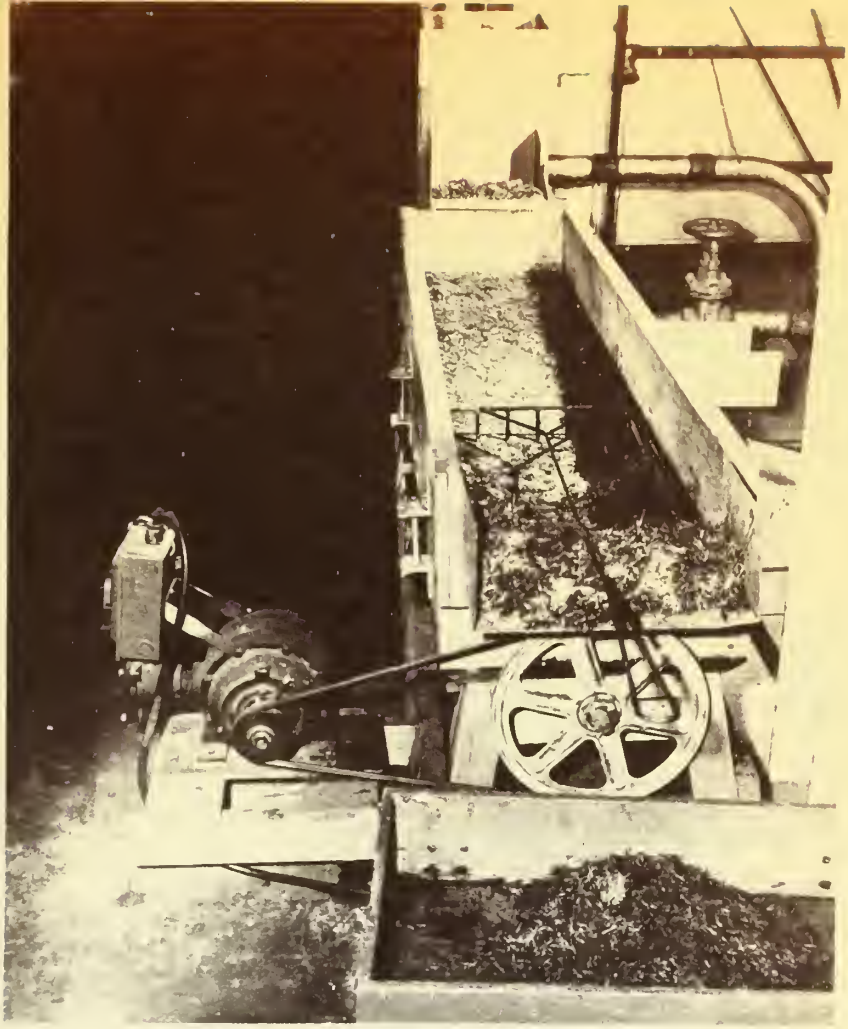


Figure 6. Screening system, chests, pumps, and Jonsson screen

Figure 7. Jonsson screen in operation



Figue 8. Flat screen in operation

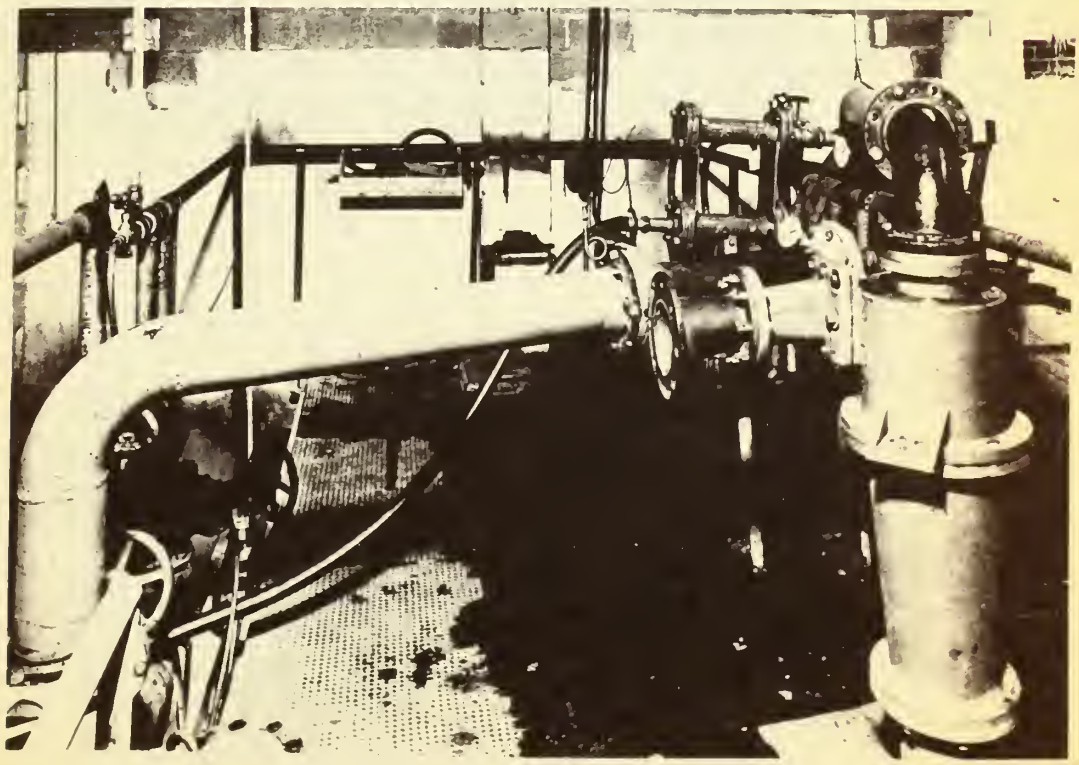


Figure 9. Centri-Cleaner in foreground

Figure 10. Vibrating screen for dewatering pith in operation

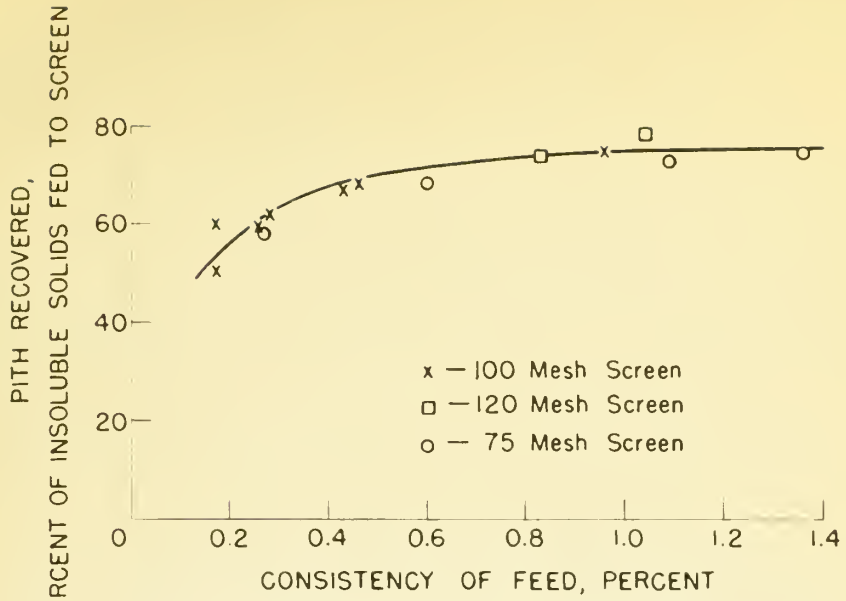


FIGURE 11. Pith Recovery vs. Feed Consistency

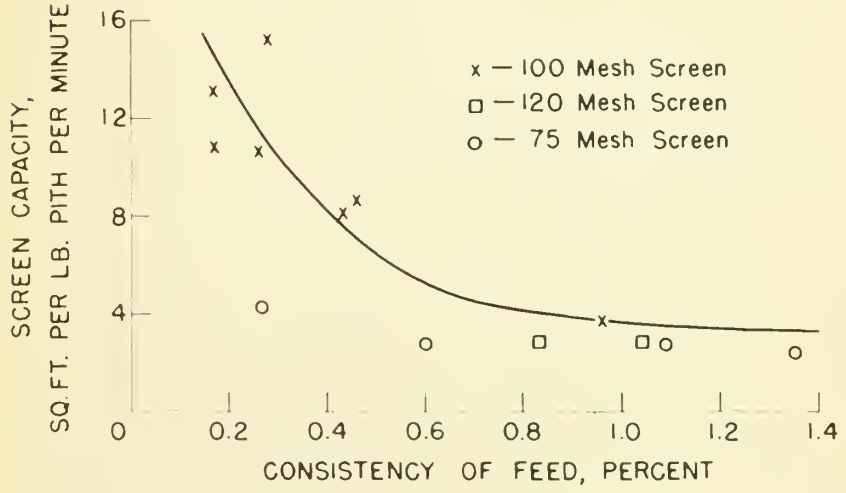


FIGURE 12. Screen Capacity vs. Feed Consistency

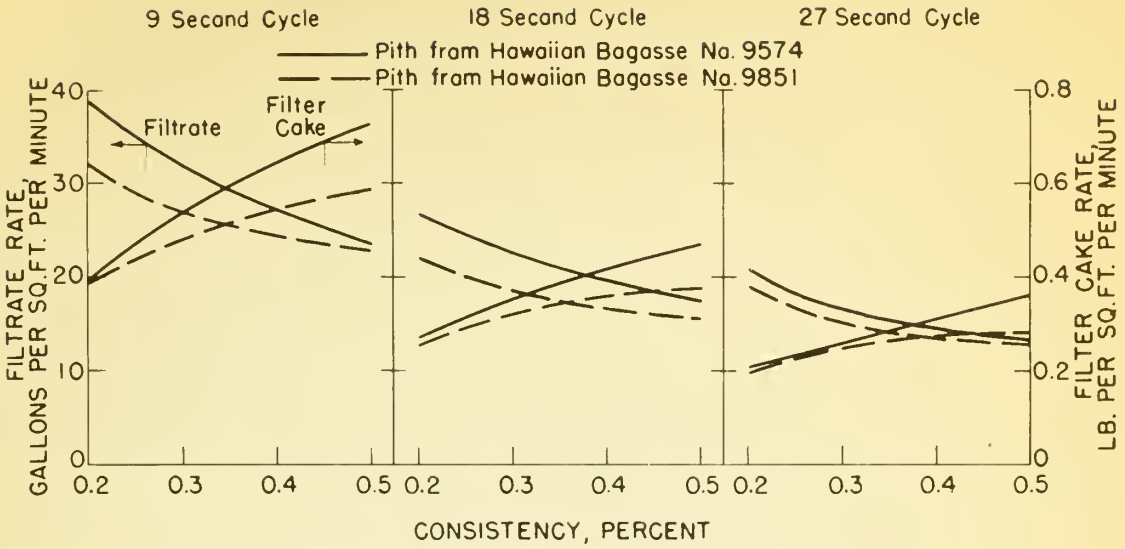

9 Second Cycle
18 Second Cycle
27 Second Cycle
Pith from Hawaiian Bagasse No. 9574
Pith from Hawaiian Bagasse No. 9851
Filtrate
Filter Cake
FILTRATE RATE, GALLONS PER SQ.FT. PER MINUTE
FILTER CAKE RATE, LB. PER SQ.FT. PER MINUTE
CONSISTENCY, PERCENT

FIGURE 13. Filtration Rate vs. Consistency

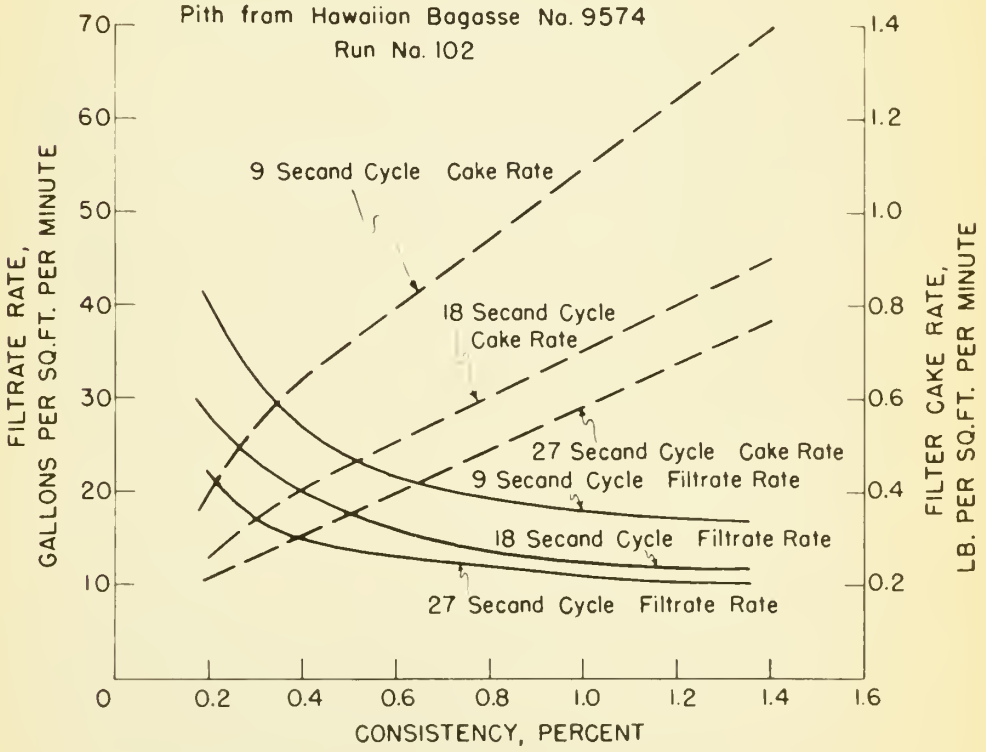

Pith from Hawaiian Bagasse No. 9574
Run No. 102
9 Second Cycle Cake Rate
18 Second Cycle Cake Rate
27 Second Cycle Cake Rate
9 Second Cycle Filtrate Rate
18 Second Cycle Filtrate Rate
27 Second Cycle Filtrate Rate
FILTRATE RATE, GALLONS PER SQ.FT. PER MINUTE
FILTER CAKE RATE, LB. PER SQ.FT. PER MINUTE
CONSISTENCY, PERCENT

FIGURE 14. Filtrate and Filter Cake Rate vs. Consistency

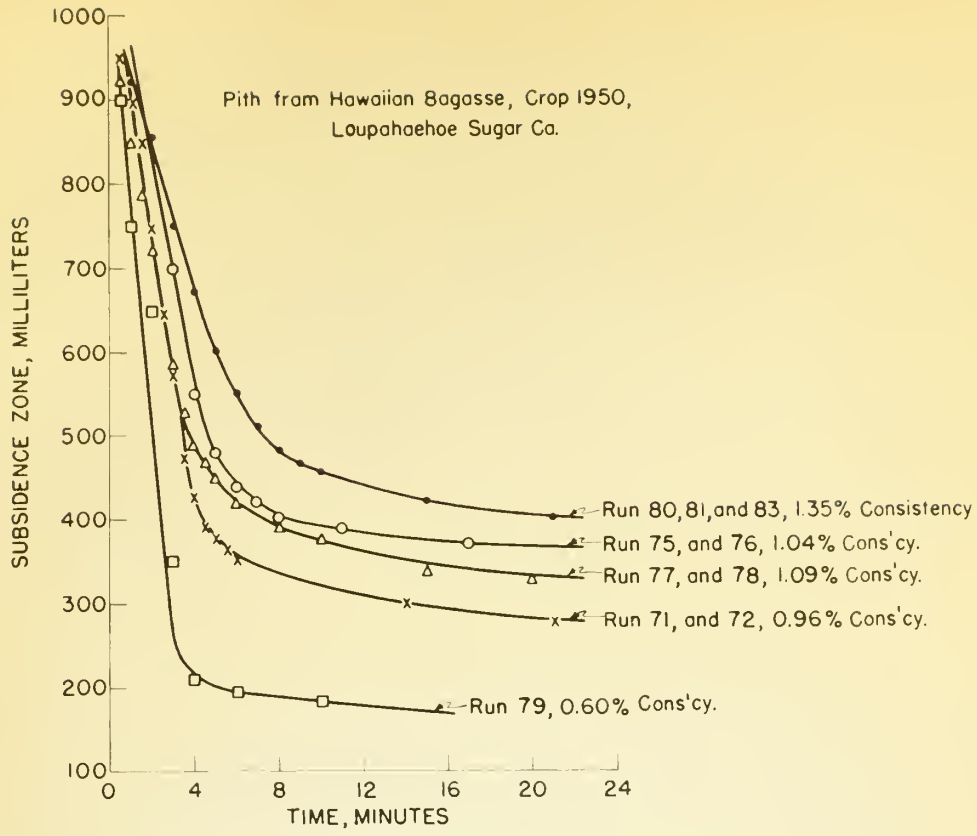

Pith from Hawaiian Bagasse, Crop 1950,
Loupahaehoe Sugar Co.
SUBSIDENCE ZONE, MILLILITERS
TIME, MINUTES
Run 80, 81, and 83, 1.35% Consistency
Run 75, and 76, 1.04% Cons'cy.
Run 77, and 78, 1.09% Cons'cy.
Run 71, and 72, 0.96% Cons'cy.
Run 79, 0.60% Cons'cy.

FIGURE 15. Subsidence Zone vs. Time

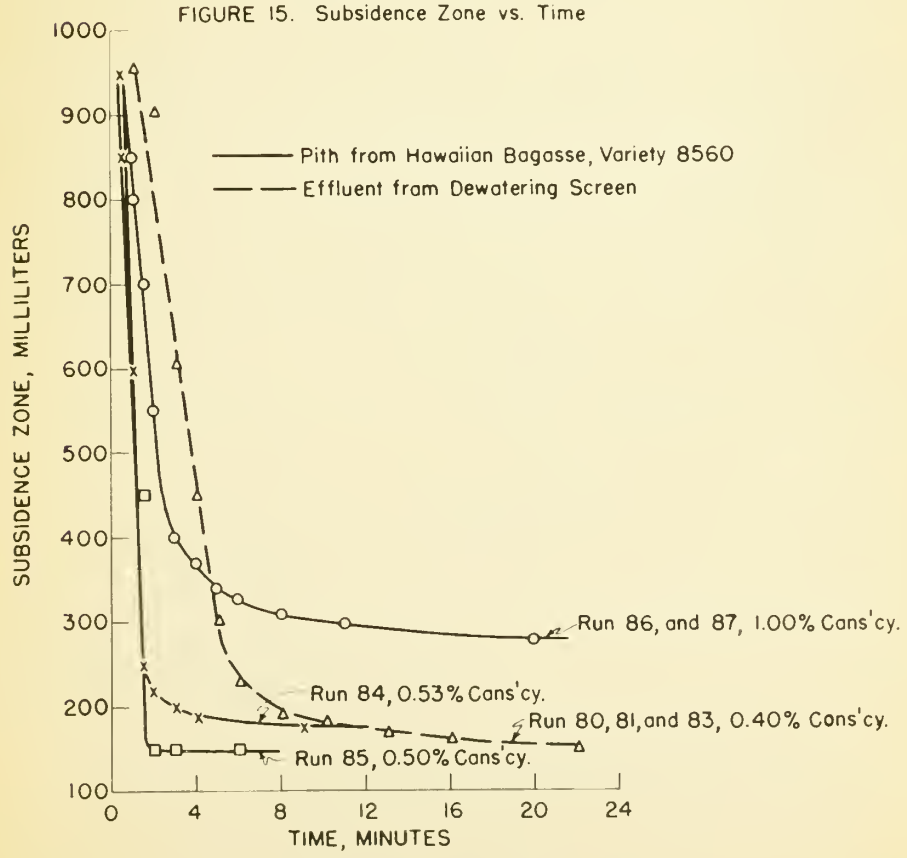

Pith from Hawaiian Bagasse, Variety 8560
Effluent from Dewatering Screen
SUBSIDENCE ZONE, MILLILITERS
TIME, MINUTES
Run 86, and 87, 1.00% Cons'cy.
Run 84, 0.53% Cons'cy.
Run 80, 81, and 83, 0.40% Cons'cy.
Run 85, 0.50% Cons'cy.

FIGURE 16. Subsidence Zone vs. Time

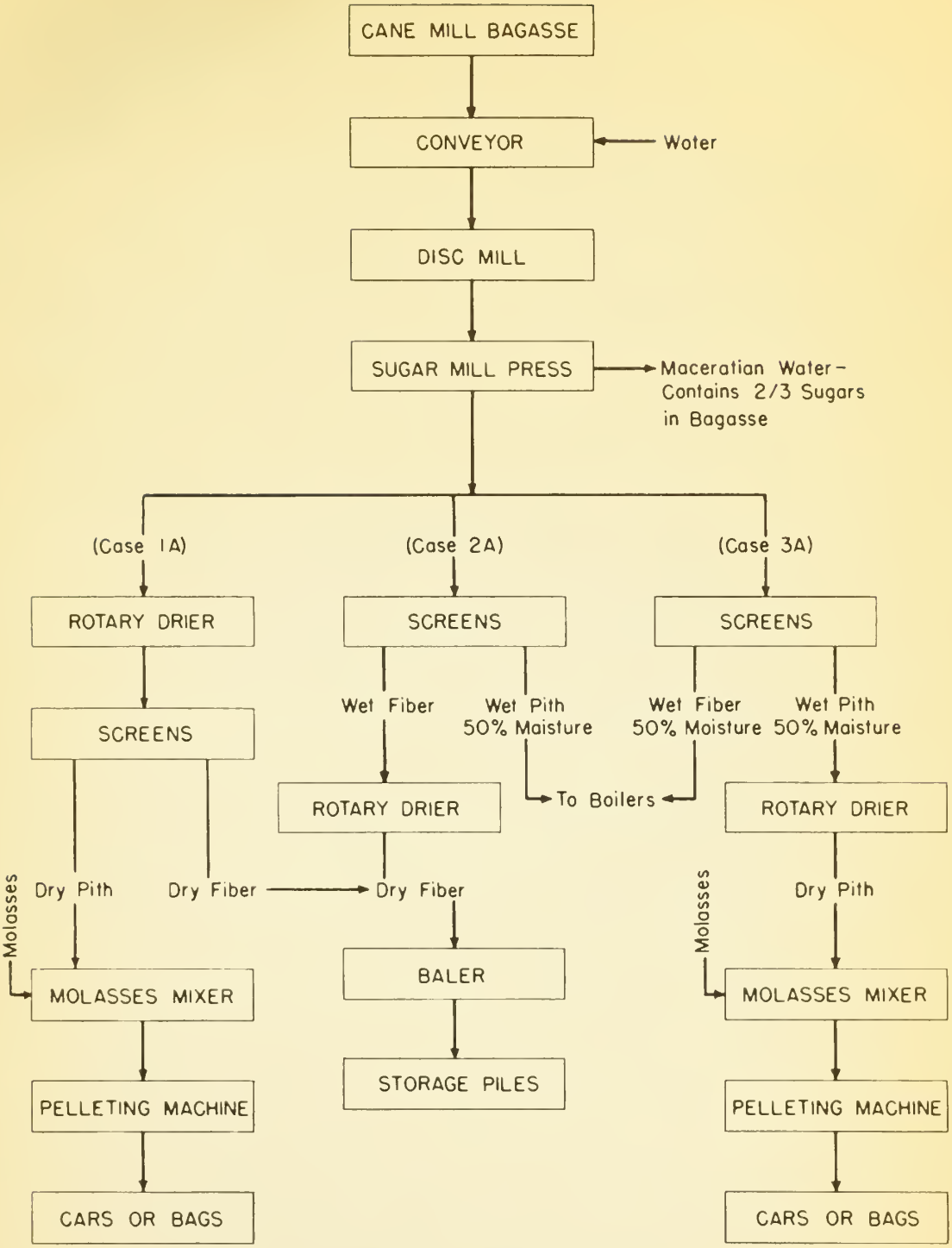


FIGURE 17. Flowsheet 1 of Disc-Mill Method for Separating Wet Bagasse at the Sugar House into Pith-free Fiber and Pith.

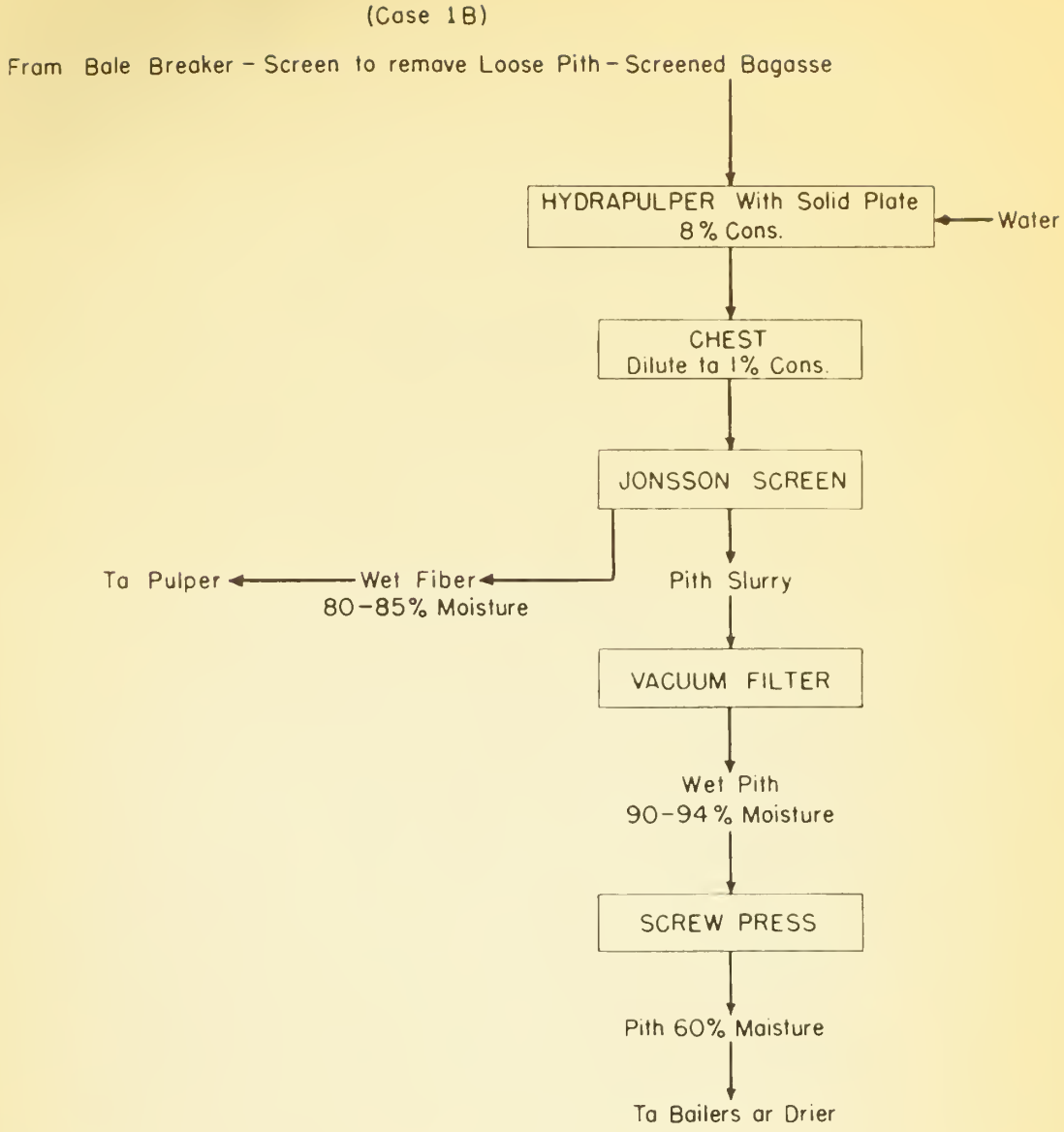


FIGURE 18. Flowsheet 2 – Solid Plate Hydrapulper Method.
Bagasse Pith–Fiber Separation.

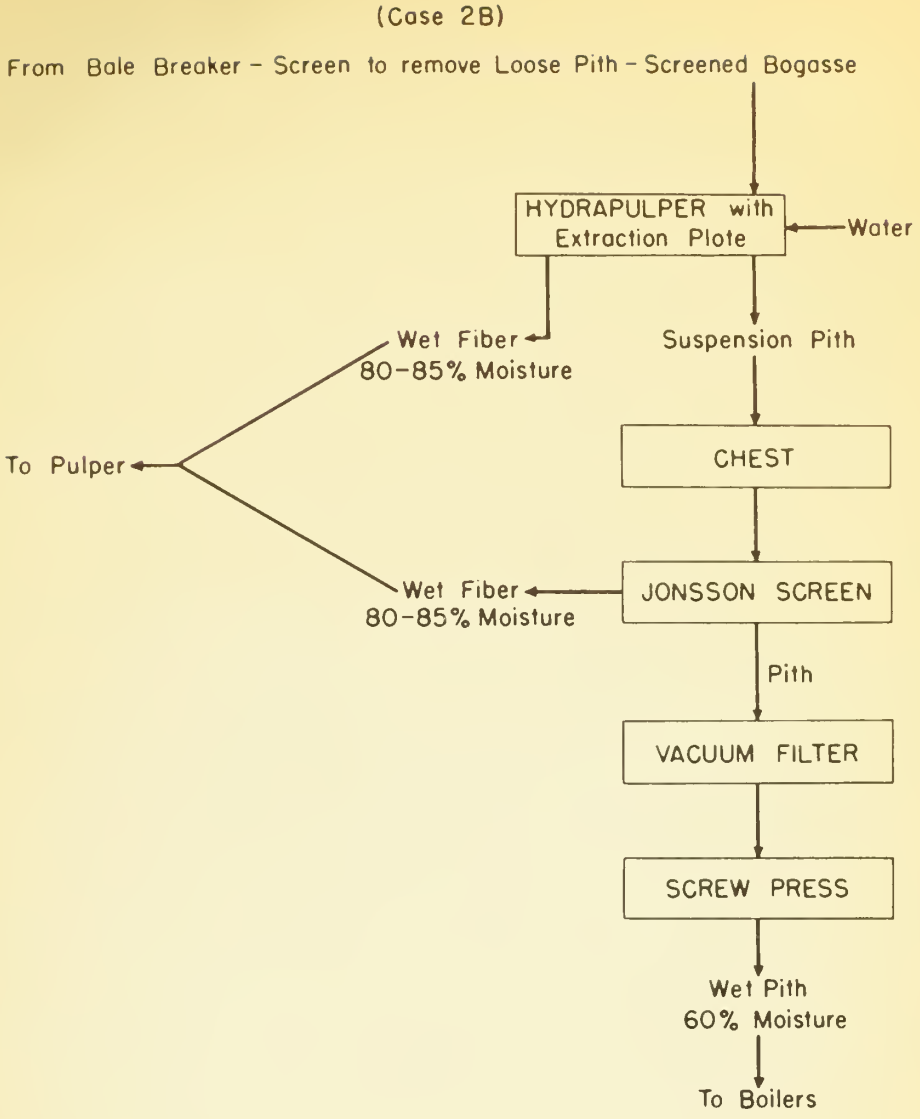


FIGURE 19. Flowsheet 3 - Hydrapulper Extraction Plate Method. Bagosse Pith-Fiber Seporotion.

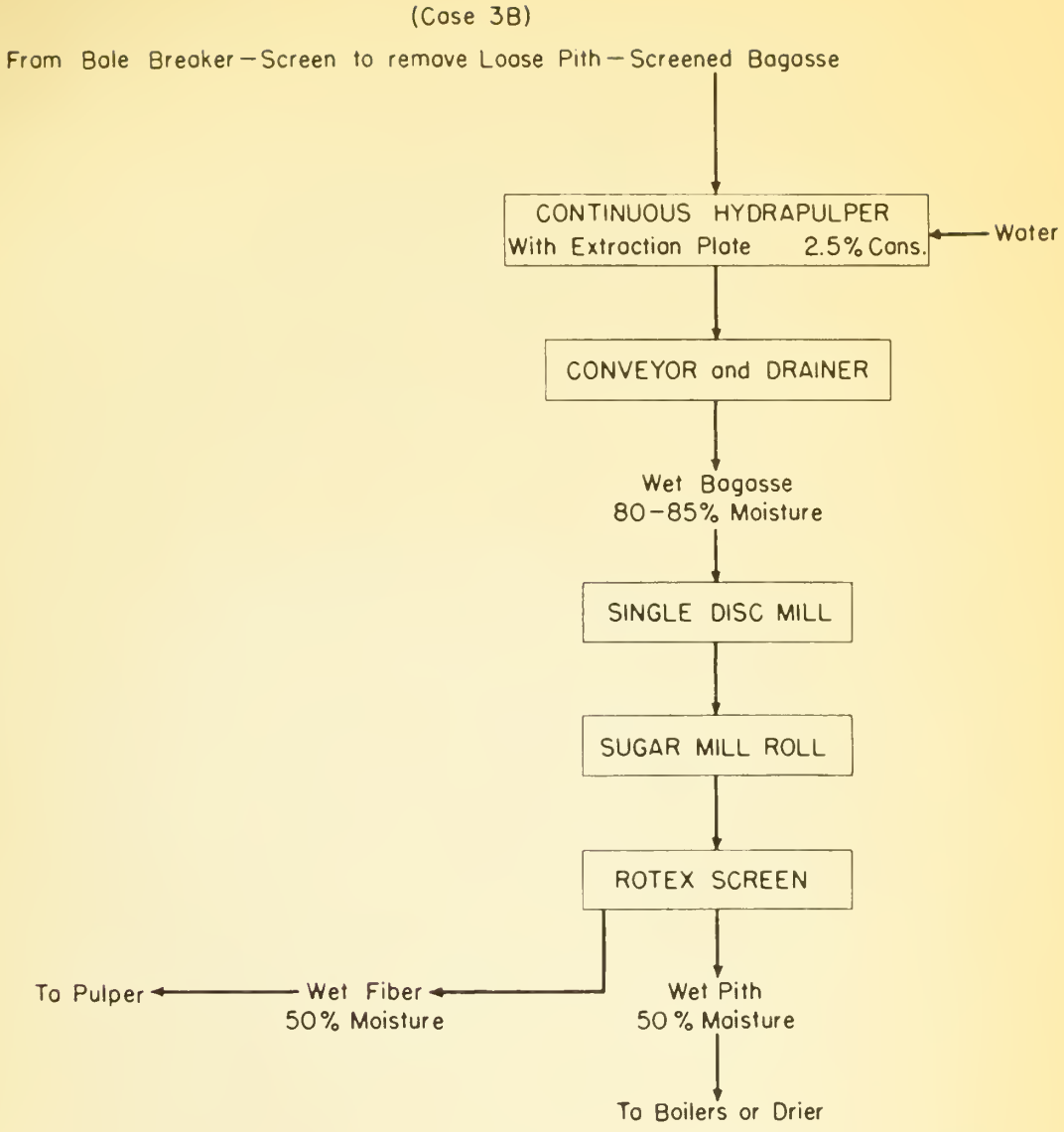


FIGURE 20. Flowsheet 4 – Continuous Hydropulper Disc-Mill Method. Bagasse Pith-Fiber Separation.